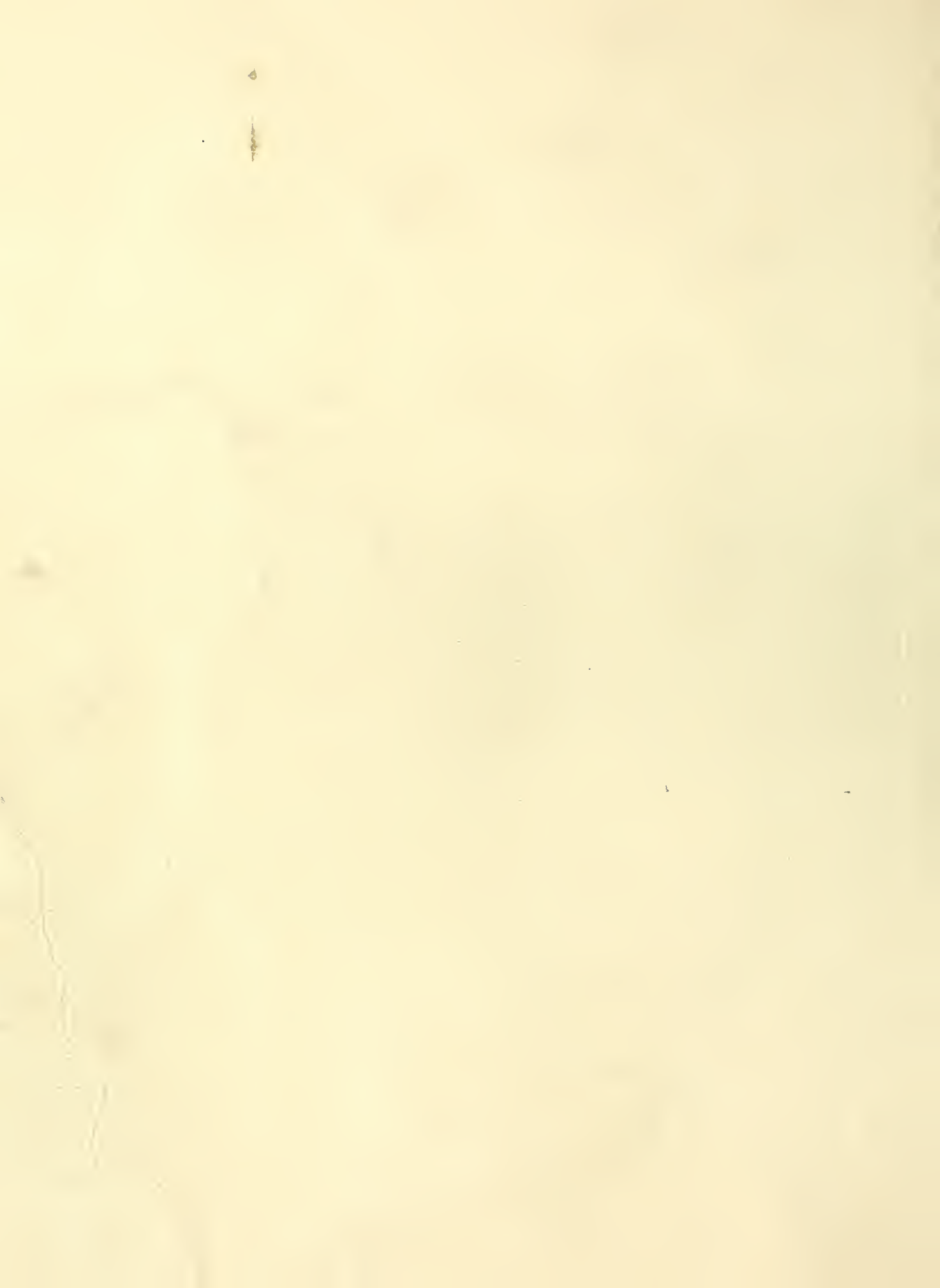


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SCHEDULING IRRIGATIONS USING A PROGRAMMABLE CALCULATOR

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CONTENTS

	Page
Introduction	1
Theory and logic of irrigation scheduling using weather data	2
Theory of potential evapotranspiration	2
Scheduling program	3
Operating instructions	5
Tabulating and initializing field data	5
Calculating potential evapotranspiration	6
Updating the schedule	7
Discussion	10
Literature cited	10
Appendix	11
A. Penman potential evapotranspiration programs	11
1. Wang Model 600, Verify number 3136	11
2. Wang Model 700, Verify number 5671	18
B. Irrigation scheduling programs	30
1. Wang Model 600, Verify number 5863 (version 11/28/72) ...	30
2. Wang Model 700A, Verify number 7503	42
C. Changes required for different locations	54
1. Adapting the scheduling programs for other crops	54
2. Modifying the Penman programs for a new calibration	55
D. Changes for Model 700A to 700B	55

SCHEDULING IRRIGATIONS USING A PROGRAMMABLE CALCULATOR¹

Dennis C. Kincaid and Dale F. Heerman²

INTRODUCTION

Using an on-location programmable calculator, irrigation schedules may be available on the same day that update calculations are made and without making long distance telephone calls to transmit data.

Computerized irrigation scheduling has been made possible by a U.S. Department of Agriculture program as developed by Jensen and associates (1969, 1970)³ for the large digital computers. It has proven reliable in arid and semiarid regions for a variety of crops, and it is now used on a commercial basis in Arizona, Idaho, and Nebraska and on applied research in Colorado and Wyoming.

During the 1969, 1970, and 1971 seasons, irrigations were successfully scheduled at the University of Nebraska Experiment Station near Mitchell, Nebr., using a Control Data Corporation 6400 computer at Colorado State University, Fort Collins. Daily weather data and irrigation data were compiled and telephoned from Mitchell to Fort Collins twice each week where the data were punched on cards and processed on the computer. The irrigation schedules were then mailed to Mitchell, arriving at the field station two days later. The delay demonstrated the need for doing the scheduling calculations at a field location.

In June 1972, a Wang 600-6 programmable calculator was obtained for the Mitchell station to make same day on-location calculations. This unit has 16 data storage registers, 824 program steps (which can be converted to data storage), a magnetic tape cassette unit for program and data storage (between updating), and an automatic drum printer. The USDA irrigation scheduling program was successfully adapted to the calculator and used during the 1972 irrigation season. The schedules were updated twice each week using the same input data as with the CDC 6400 but with a special output format suited to the calculator's tape print-out device.

The scheduling program has been adapted for the Wang Model 700 calculator which has 960 program steps. This unit also has the capability of converting program steps to data storage, and a magnetic tape cassette. The Model 700 uses typewriter output which facilitates labeling and tabulation of the data. The program also has been adapted to a Monroe 1665 but there are severe program step and data storage limitations with this machine. A complete listing of programs (for the Wang units) for calculating potential evapotranspiration and scheduling irrigations is given in the Appendix. Operating instructions, test data, and the constants used for various crops are given in the text.

The following Theory and Logic section serves as a basic reference for adapting the scheduling techniques to other types of calculator or computer systems.

¹ Research by the Agricultural Research Service, U.S. Dept. of Agr., in cooperation with the Colo. and Nebr. Agr. Exp. Stas. (Journal Series Paper Number 3604, Nebr. Agr. Exp. Sta.)

² Agricultural engineers, Agricultural Research Service, U.S. Dept. of Agr., Coshocton, Ohio (formerly of Mitchell, Nebr.), and Fort Collins, Colo., respectively.

³ References to Literature Cited, p. 00 are indicated by the name of the author(s) followed by the year of the publication in italic.

THEORY AND LOGIC OF IRRIGATION SCHEDULING USING WEATHER DATA

Theory of Potential Evapotranspiration

Potential evapotranspiration (ET) as used here is the rate of water use by a thoroughly watered reference crop — in this instance, alfalfa with 12 to 18 inches of growth. To arrive at ET, Penman (1963) developed an equation that determines the total energy available for evaporation. This is a combination equation, which means that it includes net radiation and advective energy because of wind movement. The daily potential evapotranspiration in inches of water is given by

$$E_{tp} = 0.000673 [C_1 (R_n - G) + 15.36 C_2 (1.1 + 0.017W) (e_s - e_d)] \quad (1)$$

where,

C_1 and C_2 — mean air temperature weighting factors whose sum is 1

e_s — mean saturation vapor pressure in *mb* (mean of the saturation vapor pressures at maximum and minimum daily air temperatures)

e_d — saturation vapor pressure at mean dew-point temperature in *mb* (mean of 24 hourly readings)

W — total daily wind movement in miles

R_n — daily net radiation in cal cm^{-2} (calories per square centimeter)

G — daily soil heat flux in cal cm^{-2}

The wind function coefficients $(1.1 + 0.017W)$ were calibrated with data collected at Mitchell, Nebr. These coefficients are nearly the same as those reported by Jensen (1969) for Twin Falls, Idaho.

The dimensionless weighting factors C_1 and C_2 are given by

$$C_1 = \Delta / (\Delta + \gamma) \quad (1a)$$

$$C_2 = \gamma / (\Delta + \gamma) \quad (1b)$$

where Δ is the slope of the saturation vapor pressure-temperature curve (de/dT) and γ is the psychrometric constant. C_1 and C_2 are functions of air temperature only, and for calculation purposes are given by the equations

$$C_2 = 0.959 - 0.0125 \bar{T} + 0.00004534 \bar{T}^2 \quad (1c)$$

and

$$C_1 = 1 - C_2 \quad (1d)$$

where \bar{T} is the mean daily air temperature in de-

grees F (average of maximum and minimum daily air temperature).

The saturation vapor pressure is a function of temperature and is calculated by the equation

$$e(T) = -0.6959 + 0.2946 T - 0.005195 T^2 + 89 \times 10^{-6} T^3 \quad (1e)$$

where e denotes saturation vapor pressure in *mb*, and T is the temperature in degrees F.

The soil heat flux is determined by an empirical equation

$$G = 5 \times (\bar{T} - (\bar{T}_{-1} + \bar{T}_{-2} + \bar{T}_{-3})/3) \quad (1f)$$

where \bar{T} is mean daily temperature in degrees F, and \bar{T}_{-i} is the mean air temperature for the i th previous day.

Daily net radiation is estimated by the equation

$$R_n = 0.77 R_s - \left[\frac{0.9 R_s}{R_{so}} + 0.1 \right] R_{bo} \quad (1g)$$

where

R_s — the total daily solar radiation in cal cm^{-2}

R_{so} — the total solar radiation that would be expected on a clear day, cal cm^{-2}

R_{bo} — the net outgoing longwave radiation on a clear day, cal cm^{-2}

the first term $(0.77 R_s)$ represents the net short-wave radiation absorbed by a green crop at full cover. The remaining term represents the net outgoing longwave radiation. The coefficients 0.9 and 0.1 were determined from data from Mitchell, Nebr. At this location, R_{so} is estimated by the equation

$$R_{so} = 760 \exp \left[-\frac{\text{Day} - 107}{157} \right]^2 \quad (1h)$$

where Day 1 = March 1 and R_{bo} is computed by the equation

$$R_{bo} = (0.37 - 0.044 \sqrt{e_d}) (11.71 \times 10^{-8}) \left[\frac{T_a^4 + T_b^4}{2} \right] \quad (1i)$$

11.71×10^{-8} is the Stefan-Boltzmann constant in $\text{cal cm}^{-2} \text{ day}^{-1} \text{ } ^\circ\text{K}^{-4}$, and T_a and T_b are respectively the maximum and minimum daily air temperatures in $^\circ\text{K}$. The coefficients (0.37, 0.044) were calibrated with data from Mitchell. Calibration techniques were those used by Wright and Jensen (1972).

Scheduling Program

A flow chart of the irrigation scheduling program is shown in figure 1. The program maintains a water budget on each field, starting at a time at which the soil water depletion is known or can be determined. Twice each week the depletion of each field is determined based on calculated ET and rainfall and irrigation amounts. When the update is completed, the depletion is compared with the optimum (maximum desirable) depletion to determine when irrigation is required. The irrigation amount to apply is the depletion divided by an assumed irrigation efficiency.

If the depletion at present is greater than optimum, the day to irrigate is calculated to approximate the day when optimum depletion was reached. This gives an indication of the delay in irrigating that field. If the current depletion is less than optimum the irrigation is forecasted. The daily ET for prediction purposes is calculated on

Table 1.—Guide for establishing the effective cover date

Crop	Effective cover
Small grains	.....at heading
Beans	.....bloom or about 50 days after planting
Peas	.....full bloom or 70 days after planting
Potatoes	.....about 80 days after planting
Sugarbeets	.....about 110 days after planting
Corn or sorghum	.....about 10 days after tasseling on corn and heading for sorghum
Alfalfa	.....all season except 30 days after growth begins in spring and 20 days after cuttings
Pasture	.....all season except 30 days after growth begins in the spring

the basis of a climatic average potential ET curve for a given location. The average potential at Mitchell, Nebr., is given by

$$E_{ta} = 0.3 \exp - \left[\frac{\text{Day} - 137}{\Delta \text{Day}} \right]^2 \quad (2)$$

where day 1 – March 1

$$\Delta \text{ Day} = 150 \text{ if Day} < 137$$

and $\Delta \text{ Day} = 95$ if $\text{Day} > 137$

Near the end of the growing season the crop water use rate approaches zero since both the potential ET and the crop coefficient (equation 3) are decreasing. An additional irrigation may not be required where the depletion is low at the time of a late season update. The program stops incrementing the day when the depletion has been determined to November 1.

The determination of daily water use involves a crop coefficient K_{co} which is defined as the ratio of the crop ET to the potential ET for a given day under thoroughly watered conditions. This empirical coefficient varies with time depending upon the type of crop, its planting date, and effective cover date (table 1) or expected date of peak water use. For calculation purposes, K_{co} is given as a polynomial function of the date

$$K_{co} = Ar^3 + Br^2 + Cr + D \quad (3)$$

where A , B , C , and D are constants. Before the effective cover date, r is the *fraction of time* from planting to effective cover. After effective cover, r is the *number of days* beyond the effective cover

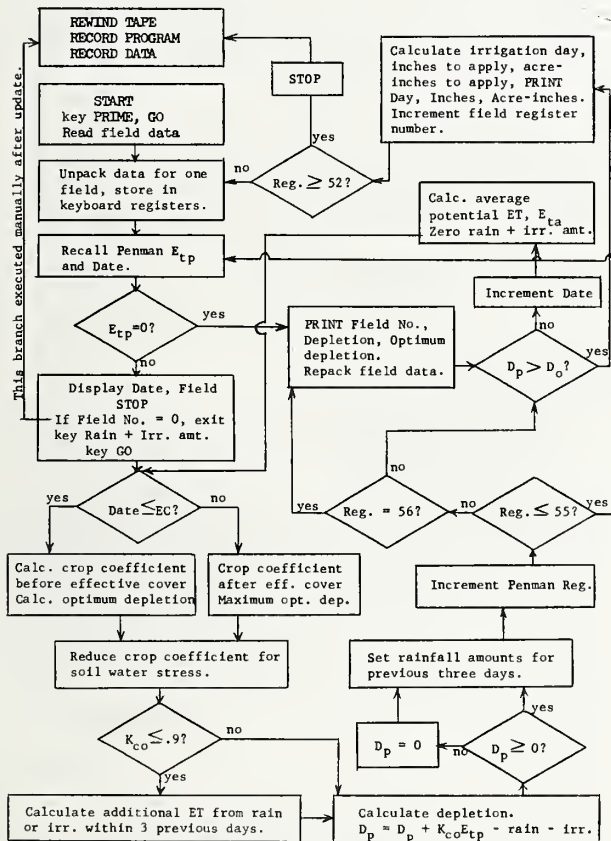


Figure 1. — Flow chart for the irrigation scheduling program.

date. Two sets of constants are used for each crop (table 2), and the crop curves at Mitchell are plotted in figures 2 through 5. These are standard crop curves derived from data taken at several locations in semiarid regions by Jensen and others (1969, 1970, 1971).

Table 2. — Polynomial constants for crop curves

Crop	Constant			
	A	B	C	D
Before effective cover				
Corn	-1.583	2.756	-.4276	0.213
Sugarbeets . .	-1.435	2.382	-.2259	.200
Beans	-1.353	2.562	-.3532	.212
Alfalfa . . . .	.0	.0	1.087	.250
Small grain . .	-2.893	4.843	-1.140	.233
Peas	-1.321	2.470	-.3067	.211
Potatoes . . .	-1.381	2.456	-.3710	.213
Pasture . . . .	.0	.0	1.508	.25
After effective cover				
Corn	275×10^{-8}	-4688×10^{-7}	0.01195	0.915
Sugarbeets . .	-167×10^{-8}	5×10^{-5}	.0	.899
Beans	165×10^{-8}	-2644×10^{-7}	-112×10^{-6}	1.05
Alfalfa . . . .	.0	.0	.025	.5
Small grain . .	444×10^{-8}	-7261×10^{-7}	8532×10^{-6}	1.022
Peas	-221×10^{-7}	-9865×10^{-7}	-101×10^{-4}	1.005
Potatoes . . .	.0	.0	.0	.90
Pasture . . . .	.0	.0	.0	.87

The crop curve for alfalfa is unique in that the water use decreases after each harvest until re-growth occurs. The planting date for alfalfa is set equal to the approximate time at which growth starts. The effective cover date is initially set to the approximate date of first cutting. After the first cutting occurs and for each cutting thereafter, the effective cover date is set equal to the last cutting date. K_{co} is not allowed to exceed a value of 1.

The daily crop ET depends upon the availability of soil water, and decreases as the depletion increases. The crop coefficient K_{co} is multiplied by the stress factor

$$K_s = \log \frac{[1 + 100 (1 - D_p / D_T)]}{\log (101)} \quad (4)$$

where D_p is the soil water depletion and D_T is the total available water within the root zone at field capacity.

The optimum depletion D_o is an assumed constant fraction of the total available water. The root zone expands with time from planting until a maximum depth is reached near the effective cover date. For simplicity, the computed rooting depth increases linearly from a minimum value at planting to a maximum value at effective cover. Table

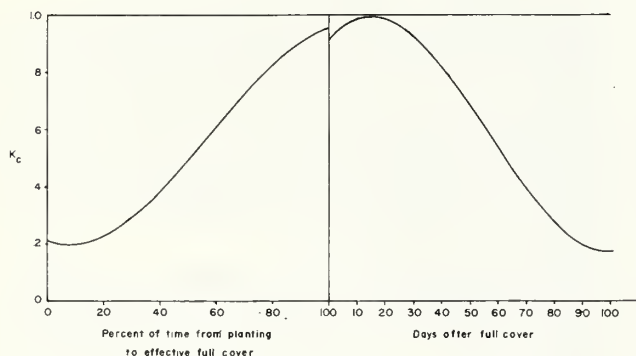


Figure 2. — Ratio of crop ET to potential ET for corn.

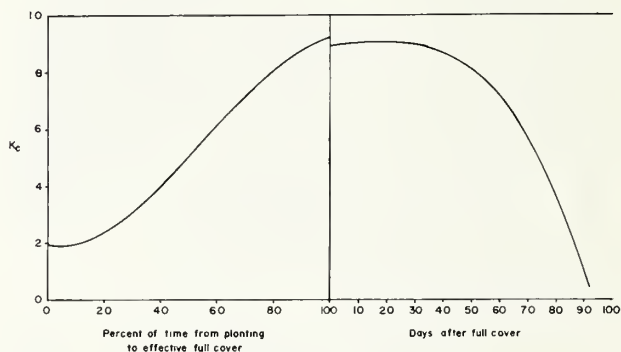


Figure 4. — Ratio of crop ET to potential ET for sugarbeets.

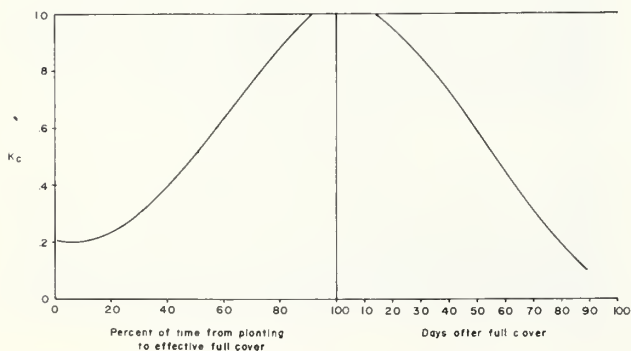


Figure 3. — Ratio of crop ET to potential ET for beans.

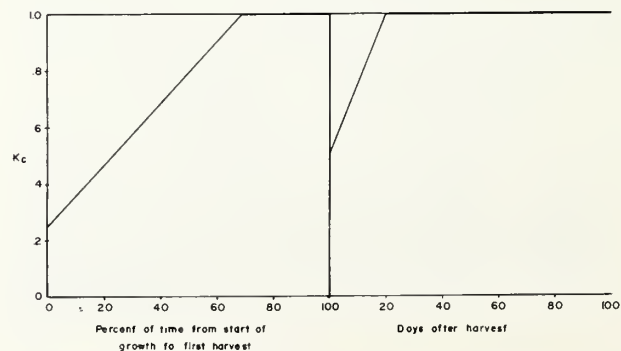


Figure 5. — Ratio of crop ET to potential ET for alfalfa.

Table 3. — Initial and maximum root zone depths

Crop	Depth at planting	Depth after effective cover
	Feet	Feet
Corn	0.5	4.0
Sugarbeets	0	3.5
Beans .....	.5	3.0
Alfalfa	6.0	6.0

3 lists the root depths used for each crop at Mitchell. The initial depths were chosen such that a linear increase from planting to effective cover would approximate the actual root development.

When irrigations are scheduled near the planting date, the root zone may be too small. Optimum depletion in this program is taken as 50 percent of the total available water within the root zone. For example, the water holding capacity of the fine sandy loam soil at Mitchell is approximately 2.7 inches per foot. One inch of water per foot is unavailable, leaving 1.7 inches available, and .85 inch as the optimum depletion per foot. The optimum depletion per foot is stored for each field and can be adjusted from zero to one inch to account for varying soil types within a group of fields. The optimum depletion per foot can also be reduced to account for a shallow soil profile on an individual field. The optimum depletion D_o is the rooting depth times the optimum depletion per foot.

The daily water use is less than the potential

water use whenever K_{co} is less than one. However, immediately following an irrigation or rainfall, the water use will be near potential because of evaporation from the soil surface. The additional water use because of evaporation on a given day is determined by the equation

$$E_{tr} = K_r (0.9 - K_c) E_{tp} \quad (5)$$

where

E_{tp} — the potential evapotranspiration

K_c — the crop coefficient determined by the stage of growth and soil water depletion

($K_c = K_{co} K_s$), and

K_r — a coefficient taking on the values of

0.8 for the first day,

0.5 for the second day,

0.3 for the third day following rainfall or irrigation, respectively.

If $K_c \geq 0.9$, or if no rain or irrigation has occurred within 3 days, then E_{tr} is equal to zero. The water balance equation, applied to each field for each day, is

$$D_{pi} = D_{pi-1} + K_c E_{tp} + E_{tr} - R_i \quad (6)$$

where

D_{pi} — the depletion on Day i and

R_i — the sum of rainfall and irrigation for Day i .

If R_i is larger than the previous depletion plus ET, then the depletion is set to zero. Irrigation amounts often cannot be measured and must be estimated, unless it is assumed that irrigation was sufficient to replenish the soil water to field capacity.

OPERATING INSTRUCTIONS

Tabulating and Initializing Field Data

Scheduled fields are updated in groups of up to 18 fields (12 fields on the Wang 700) in a single crop. The data for each individual field or scheduled area are stored in two consecutive data registers starting with register 16 (20 on the Model 700). The data are packed into the registers to utilize the entire 12 digit capacity of each register. The data required for each field are as follows:

1. Data for such even numbered registers as 16 or 18
 - a. Field number, 2 digits.
 - b. Irrigation efficiency, percent, 2 digits.
 - c. Crop area, acres multiplied by 10, 3 digits.
 - d. Optimum depletion, inches per foot by 100, 2 digits.
 - e. Soil moisture depletion, inches by 100, 3 digits.
2. Data for odd numbered registers, 17 or 19
 - a. Rain or irrigation up to 1 inch for first day before first day of update, inches multiplied by 100, 2 digits.
 - b. Rain for second previous day, inches by 100, 2 digits.
 - c. Rain for third previous day, inches by 100, 2 digits.
 - d. Planting date (Day 1 — March 1), 3 digits.
 - e. Effective cover date (Day 1 — March 1), 3 digits.

Table 4. — Sample field data for testing the scheduling program

Register number ¹	Field number	Efficiency	Acres	Optimum depletion/ft
16.....	017503485332			
18.....	027505085255			
20.....	037004250115			
22.....	047002550065			
24.....	056510060135			
26.....	066520060085			
28.....	076032070225			
30.....	086035070170			
32.....	095545080305			
34.....	105550080025			
36.....	115001599110			
38.....	125090099250			

Register number	R-1	R-2	R-3	Planting date	Cover date
17.....	010101065132				
19.....	010000065132				
21.....	000101065132				
23.....	000100065132				
25.....	000001065132				
27.....	900000065132				
29.....	909090065132				
31.....	009000065132				
33.....	000090065132				
35.....	000000065132				
37.....	000000065132				
39.....	000000065132				

¹ The register numbers listed are for the Model 600 program. The Model 700 program stores data in registers 20-43.

The field number is an identifier for a scheduled area which may include more than one actual field. The acreage is the total area scheduled as one field up to 100 acres. Fields larger than 100 acres could be stored as whole acres, and the resulting volume in acre-inches multiplied by 10. The irrigation efficiency is estimated as the expected percentage of the total water applied which is added to the root zone of the crop. The soil moisture depletion may be set to zero at the beginning of the season or may be estimated. The depletion can be adjusted if necessary at any time during the season. The rainfall amounts may be set to zero initially. Rain or irrigation in excess of .99 inch is disregarded for previous days. The effective cover date is the expected date of peak water use and may be constant for a given crop.

The above data are keyed into display in the order given and then stored manually into the proper register. The value of all unused field registers should be set to zero.

The field data stored in the calculator memory are transferred to magnetic tape as one block of data. Model 700 processes the field data as part of the scheduling program for each crop, and the program and field data are recorded in one operation. Wang 600 processes data separately from the program. A block of fields is recorded on tape by keying 51 alpha store, since all registers up to

51 are available for field data. The data should be recorded immediately following the scheduling program for that particular crop on the Model 600.

Table 4 lists a sample set of field data which can be used for testing the scheduling programs.

Calculating Potential Evapotranspiration

The daily potential ET is calculated with the modified Penman equation as calibrated at Mitchell, Nebr. The data required are daily maximum and minimum air temperatures, mean dewpoint temperature in degrees F, total solar radiation in Langleys, and total wind movement in miles at 2 meters above the ground. These data are totaled or averaged from midnight to midnight each day.

The weather data are tabulated for each day of update and keyed into the calculator before running the scheduling programs. The steps involved are as follows:

1. Load and verify the Penman program, turn printer on. (Model 700 — Load and verify Penman program, PRIME and G0)
2. Key the average temperature for the third day before the first day of update, \bar{T}_{-3} . (Model 700 — Manually type in beginning date, return typewriter to automatic and depress G0.)
3. Key Search 0.
4. Key average temperature for the second previous day, \bar{T}_{-2} key G0.
5. Key average temperature for the first previous day, \bar{T}_{-1} key G0.
6. Key the first day of update (Day 1 — March 1), key G0.
7. Key maximum temperature for the day printed, key G0.
8. Key minimum temperature, key G0.
9. Key dewpoint temperature, key G0.
10. Key solar radiation, key G0.
11. Key wind, key G0.
12. Repeat steps 7-11 for up to 4 days of update.

The Penman program sums the day number and calculated potential ET for each day. These values are stored in registers 52-55 (12-15 on the Model 700). When only 3 days are calculated, the potential ET for the fourth day is set equal to zero. The printed output lists average temperature, mean vapor pressure, dewpoint vapor pressure, soil heat flux, net radiation, and potential ET as well as the input data. An example of the weather data print-out, Model 600, is shown in table 5 for two 4-day

Table 5. — Daily weather data and calculated potential ET, Model 600

Day	72.	73.	74.	75.	201.	202.	203.	204.
Maximum temperature	55.	54.	59.	72.	85.	88.	80.	68.
Minimum temperature	44.	38.	38.	36.	53.	49.	51.	50.
Dewpoint temperature	30.	28.	26.	27.	31.	35.	41.	29.
Radiation R_s	100.	200.	381.	551.	504.	486.	283.	505.
Wind run, miles	108.	204.	338.	149.	139.	78.	141.	164.
Average temperature	¹ 49.5	¹ 46.0	¹ 48.5	¹ 54.0	² 69.0	² 68.5	² 65.5	² 59.0
Mean vapor pressure	12.194	10.979	12.380	17.066	27.521	28.693	23.907	17.735
Dewpoint vapor pressure	5.869	5.433	5.016	5.222	6.095	7.067	8.783	5.649
Soil heat flow, G	15.00	1.66	10.83	30.00	32.50	17.50	-12.50	-43.33
Net radiation, R_n	32.	86.	177.	260.	170.	168.	98.	179.
Potential ET	.093	.155	.300	.275	.303	.240	.232	.277

¹ Average temperatures before day 72 were $\bar{T}_{-3} = 52.0$, $\bar{T}_{-2} = 44.0$, $\bar{T}_{-1} = 43.5$.

² Average temperatures before day 201 were $\bar{T}_{-3} = 61.5$, $\bar{T}_{-2} = 59.5$, $\bar{T}_{-1} = 66.5$.

Table 6. — Calculated weather data and potential ET, Model 700

LOCATION Scottsbluff BEGINNING DATE May 11								
DAY	TAVG	RS	UA	VPS	VPD	RN	G	EO
72	49.5	100	108.0	12.1	5.8	32	15.0	.093
73	46.0	200	204.0	10.9	5.4	86	1.6	.155
74	48.5	381	338.0	12.3	5.0	177	10.8	.300
75	54.0	551	149.0	17.0	5.2	260	30.0	.275
LOCATION Scottsbluff BEGINNING DATE September 17								
DAY	TAVG	RS	UA	VPS	VPD	RN	G	EO
201	69.0	504	139.0	27.5	6.0	170	32.5	.303
202	68.5	486	78.0	28.6	7.0	168	17.5	.240
203	65.5	283	141.0	23.9	8.7	98	-12.5	.232
204	59.0	505	164.0	17.7	5.6	179	-43.3	.277

periods. The calculator prints the data on paper tape which is posted on a previously prepared form.

The output for the Model 700 is shown in table 6. The Model 700 Penman program also prints the heading for the output of the scheduling programs. A separate sheet is inserted and Search 2 is keyed for printing the heading for the schedule output.

Updating the Schedule

After the Penman program has been run, the dates and potential ET values are in memory and will remain there until the scheduling is completed. The next step is to insert a tape containing a scheduling program and data. After loading the program, key PRIME, GO, and the first field number will appear with the date in display. The field number will be to the right of the decimal (register X on the Model 700). At this point, the field data have been unpacked and are stored in registers 0 to 6, 8, and 11 as follows:

Register	Data stored
0	... Effective cover date
1	... Rainfall for previous day
2	... Rainfall for second previous day
3	... Rainfall for third previous day
4	... Planting date
5	... Irrigation efficiency, acres and optimum depletion per foot (stored as an unpacked number)
6	... Depletion
8	... Date
11	... Field number ¹

¹ Model 700 includes the field number in register 5, not register 11.

Adjustments may be made to any of the above data by restoring the desired values in the indicated registers. For example, the effective cover date for alfalfa that has just been cut can be changed by entering the date and storing directly

Table 7.—Updated irrigation schedule, Model 600, beginning September 17

Crop: Corn			
Field number	1.	5.	9.
Depletion, inches	.22	1.72	3.42
Optimum depletion	3.40	2.40	3.20
Day to irrigate	—1.	222.	202.
	none	Oct. 8	Sept. 18
Inches to apply	2.0	3.8	6.1
Acre-in. to apply	6.8	37.1	277.9
Field number	2.	6.	10.
Depletion, inches	2.92	1.50	.27
Optimum depletion	3.40	2.40	3.20
Day to irrigate	215.	233.	—1.
	Oct. 1	Oct. 19	none
Inches to apply	4.5	3.6	2.8
Acre-in. to apply	22.7	73.9	141.1
Field number	3.	7.	11.
Depletion, inches	1.54	2.84	.28
Optimum depletion	2.00	2.80	3.96
Day to irrigate	214.	204.	—1.
	Sept. 30	Sept. 20	none
Inches to apply	2.8	4.7	3.1
Acre-in. to apply	11.9	150.9	4.7
Field number	4.	8.	12.
Depletion, inches	.22	0.00	2.87
Optimum depletion	2.00	2.80	3.96
Day to irrigate	—1.	—1.	245.
	none	none	Oct. 31
Inches to apply	2.1	2.2	7.7
Acre-in. to apply	5.3	79.6	700.6

into register 0. A measurement of the actual depletion may be stored directly into register 6 if an adjustment is required. These adjusted values will then be used in calculating a new irrigation schedule and be repacked for the next update. For each day of update, key the sum of rainfall plus irrigation water applied and depress G0. The new depletion will be calculated and the next day will appear in display. When the last day of update is com-

Table 8.—Updated irrigation schedule, Model 700, location Scottsbluff beginning September 17

Field	Depletion			Amount to apply		
	Estimated	Optimum	Day to irrigate	Inches	Acre-inches	
Corn						
1	.22	3.40	247	¹ Nov. 2	2.0	6.8
2	2.92	3.40	215	Oct. 1	4.5	22.7
3	1.54	2.00	214	Sept. 30	2.8	11.9
4	.22	2.00	247	Nov. 2	2.1	5.3
5	1.72	2.40	222	Oct. 8	3.7	37.1
6	1.50	2.40	233	Oct. 19	3.6	73.9
7	2.84	2.80	204	Sept. 20	4.7	150.9
8	.00	2.80	247	Nov. 2	2.2	79.6
9	3.42	3.20	202	Sept. 18	6.1	278.0
10	.27	3.20	247	Nov. 2	2.8	141.2
11	.28	3.96	247	Nov. 2	3.1	4.7
12	2.87	3.96	245	Oct. 31	7.7	700.7

¹ Day 247 indicates no irrigation is needed. Amount to apply is the depletion as of November 1.

pleted, the calculator will automatically printout the field number, updated depletion, calculated optimum depletion, the day to irrigate, inches of water to apply, and volume of water required in acre-inches. These data are repacked and those for the next field are then recalled. The field number for the latter will appear in display along with beginning day for update. Each field is updated in the same manner.

When all fields have been updated, the field number appearing in display will be zero providing there are less than 18 (12 on the Model 700) fields in the block. At this point a field may be added to the schedule simply by storing the required data in registers 0 to 6, 8, 11, and updated. The data for the new field are repacked after the updating is completed and will be stored on the magnetic tape for use in the next update.

Table 9. — Sample rainfall-irrigation data for updating the schedule

Day number	Field number											
	1	2	3	4	5	6	7	8	9	10	11	12
72 ..	0	0	0	0.5	0.00	0.00	3	0	0.25	0.0	1.0	1.5
73 ..	0	0	0	.5	.01	.01	0	0	.00	.0	.0	0
74 ..	4	0	0	.5	.00	.00	0	0	3.30	.5	.5	0
75 ..	0	0	0	.0	.01	.01	0	3	.00	.0	.0	0
201 ..	0	0	0	.5	.00	.00	0	0	.25	.0	1.0	0
202 ..	0	0	0	.5	.01	.01	0	0	.00	.0	.0	0
203 ..	4	0	0	.5	.00	.00	0	0	.00	.5	.5	0
204 ..	0	0	0	.0	.01	.01	0	3	.00	.0	.0	0

Table 10.—Updated depletions and irrigation dates for test runs before cover, beginning May 11

Field number	Depletion inches	Optimum depletion inches	Day to irrigate	Inches to apply	Acre-inches
Corn:					
1...	0.20	0.86	94	2.2	7.7
2...	1.54	.86	55	2.0	10.2
3...	.94	.51	61	1.3	5.6
4...	.20	.51	82	1.0	2.5
5...	1.04	.61	63	1.6	16.1
6...	1.21	.61	14	1.8	37.1
7...	.39	.71	88	1.9	63.3
8...	.00	.71	90	2.0	73.3
9...	.20	.81	93	2.9	130.7
10...	.20	.81	93	2.9	145.1
11...	.20	1.01	99	4.6	6.9
12...	.50	1.01	97	4.3	388.2
Beets:					
1...	.20	.44	83	1.0	3.6
2...	.67	.44	70	.9	4.5
3...	.46	.26	70	.6	2.8
4...	.20	.26	75	.4	1.2
4...	.47	.31	72	.7	7.3
6...	.61	.31	56	.9	18.9
7...	.39	.36	75	.6	20.9
8...	.00	.36	80	.9	32.3
9...	.20	.41	81	1.2	55.3
10...	.20	.41	81	1.2	61.4
11...	.20	.51	88	2.3	3.5
12...	.39	.51	87	2.2	203.3
Beans:					
1...	.20	.74	88	1.5	5.3
2...	1.34	.74	57	1.7	8.9
3...	.83	.43	60	1.1	5.0
4...	.20	.43	78	.7	1.8
5...	.94	.52	63	1.4	14.4
6...	1.01	.52	52	1.5	31.1
7...	.39	.61	83	1.4	44.8
8...	.00	.61	85	1.4	51.1
9...	.20	.69	87	1.9	89.1
10...	.20	.69	87	1.9	98.9
11...	.20	.86	91	2.9	4.3
12...	.39	.86	91	2.9	264.6
Alfalfa:					
1...	.22	5.10	104	6.8	23.3
2...	2.86	5.10	92	6.8	34.0
3...	1.47	3.00	88	4.4	18.5
4...	.22	3.00	94	4.3	10.7
5...	1.65	3.60	90	5.5	55.4
6...	1.34	3.60	92	5.5	111.9
7...	.47	4.20	100	7.2	231.8
8...	.00	4.20	101	7.1	251.1
9...	.22	4.80	103	8.8	398.3
10...	.22	4.80	103	8.8	442.1
11...	.22	5.94	108	12.2	18.3
12...	1.49	5.94	103	11.8	1066.2

Table 11.—Updated depletions and irrigation dates for test runs after cover, beginning September 17

Field number	Depletion inches	Optimum depletion inches	Day to irrigate	Inches to apply	Acre-inches
Corn:					
1...	0.22	3.40	-1(247)	2.0	6.8
2...	2.92	3.40	215	4.5	22.7
3...	1.54	2.00	214	2.8	11.9
4...	.22	2.00	-1(247)	2.1	5.3
5...	1.72	2.40	222	3.7	37.1
6...	1.50	2.40	233	3.6	73.9
7...	2.84	2.80	204	4.7	150.9
8...	.00	2.80	-1(247)	2.2	79.6
9...	3.42	3.20	202	6.1	277.9
10...	.27	3.20	-1(247)	2.8	141.1
11...	.28	3.96	-1(247)	3.1	4.7
12...	2.87	3.96	245	7.7	700.6
Beets:					
1...	0.22	2.97	-1(247)	.4	1.4
2...	3.07	2.97	204	4.0	20.4
3...	1.69	1.75	205	2.5	10.6
4...	.22	1.75	-1(247)	.4	1.1
5...	1.88	2.10	207	3.2	32.5
6...	1.57	2.10	212	3.2	65.0
7...	2.92	2.45	201	4.8	155.1
8...	.00	2.45	-1(247)	.2	9.0
9...	3.49	2.80	199	6.3	283.7
10...	.41	2.80	-1(247)	.9	46.2
11...	.36	3.46	-1(247)	.9	1.3
12...	3.02	3.46	211	6.8	619.2
Beans:					
1...	0.21	2.55	-1(247)	1.2	4.2
2...	2.83	2.55	200	3.7	18.8
3...	1.45	1.50	206	2.1	9.2
4...	.21	1.50	-1(247)	1.3	3.3
5...	1.63	1.80	208	2.7	27.6
6...	1.46	1.80	215	2.7	55.7
7...	2.78	2.10	193	4.6	147.7
8...	.00	2.10	-1(247)	1.3	47.5
9...	3.36	2.40	189	6.0	272.7
10...	.21	2.40	-1(247)	1.6	84.9
11...	.23	2.97	-1(247)	1.9	2.9
12...	2.78	2.97	209	5.8	525.3
Alfalfa:					
1...	.30	5.10	244	6.8	23.2
2...	3.52	5.10	215	6.8	34.2
3...	2.13	3.00	210	4.3	18.2
4...	.27	3.00	223	4.3	10.8
5...	2.32	3.60	213	5.6	56.3
6...	1.83	3.60	216	5.5	111.0
7...	3.21	4.20	211	7.0	226.5
8...	.00	4.20	237	7.0	246.6
9...	3.75	4.80	211	8.6	390.5
10...	.78	4.80	235	8.6	433.4
11...	.63	5.94	-1(247)	11.2	16.8
12...	3.48	5.94	222	11.8	1062.3

After updating, the tape is rewound and the program recorded, which also records the new data on the Model 700. On the Model 600, the

new data are recorded by keying Search 0. The next tape is then inserted for a different crop or group of fields and the updating process repeated.

An example of the schedule output for the 600 is shown in table 7, and for the 700 in table 8. The irrigation calendar date must be written in after the day number. A standard form is constructed on which the Model 600 calculator printouts are pasted. A field name or number may be written in to further identify the scheduled areas. Photocopies of the completed schedule are made for distribution to the irrigators and farm manager.

Table 9 lists sample rainfall and irrigation data for four days of update before and after effective cover. These data were used along with the field

data from table 4 and the climatic data from table 5 to test all of the programs on the 600 and 700 model calculators. The results of updating these data are given in tables 10 and 11. The data were constructed to test the programs under all conditions that might be encountered. The 600 and 700 programs gave identical results. The results of tables 10 and 11 were calculated with potential ET values truncated at 3 significant figures and stored manually. Slight deviations may occur in the results if the ET values are calculated and stored directly by the Penman program.

DISCUSSION

The programs and logic are documented for two different Wang programmable calculators. These programs, however, could be adapted to many other programmable calculators currently available. Modifications can be made to suit particular types of crops or irrigation systems. Instructions for changing the crop curve constants and rooting depths are given in the Appendices.

The Penman equation as given has been calibrated for such a semiarid region as western Nebraska. Slight changes in some constants may be needed in more humid regions. Potential evapotranspiration may be estimated by other means if the required data are not available for use of the

Penman method. For ease in operation, it is recommended that the calculator selected have the capability of reading and writing data on either a magnetic cassette or card.

Experience at Mitchell, Nebr., has shown that four crops divided into a total of 37 fields could be updated in 2 hours. This included tabulation of the weather and irrigation data for entry into the calculator. The same number of entries must be made on either large computers or the programmable calculator. However, when the schedule is made locally, the schedule is immediately available to the irrigator, and it is not delayed in the mail.

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APPENDIX

A. Penman Potential Evapotranspiration Programs

1. Wang Model 600, Verify Number 3136

Step	Code	Key	Comments
0000	09 00	* M	To start, key average temperature for 3rd
0001	00 00	E 0	previous day, \bar{T}_{-3} , Search 0.
0002	06 01	ST 1	
0003	09 03	* SP	Key average temperature for 2nd previous day,
0004	06 02	ST 2	\bar{T}_{-2} , key G0.
0005	09 03	* SP	Key \bar{T}_{-1} , key G0.
0006	06 03	ST 3	
0007	00 05	E 5	
0008	00 02	E 2	
0009	06 00	ST 0	Store first E_{tp} register number in 0.
0010	09 03	* SP	Key first day of update, key G0.
0011	06 04	ST 4	
0012	09 00	* M	
0013	00 01	E 1	
0014	07 04	RE 4	
0015	15 11	D 11	
0016	06 00	ST 0	Store date in E_{tp} register.
0017	08 02	* W	Print date.
0018	06 00	ST 0	
0019	09 03	* SP	Key T_{\max} , maximum temperature.
0020	06 05	ST 5	
0021	08 02	* W	Print T_{\max} .
0022	03 00	- 0	
0023	09 03	* SP	Key minimum temperature.
0024	06 06	ST 6	
0025	08 02	* W	Print T_{\min} .
0026	11 00	F 0	
0027	09 03	* SP	Key dewpoint temperature.
0028	06 07	ST 7	
0029	08 02	* W	Print T_{dp} .
0030	14 00	C 0	
0031	09 03	* SP	Key solar radiation.
0032	06 08	ST 8	
0033	08 02	* W	Print R_s .
0034	01 00	T 0	
0035	09 03	* SP	Key wind, total miles.
0036	06 09	ST 9	
0037	08 02	* W	Print W.
0038	11 00	F 0	
0039	08 02	* W	Print space.

Step	Code	Key	Comments
0040	00 15	E 15	
0041	08 02	* W	Print space.
0042	00 15	E 15	
0043	07 05	RE 5	
0044	06 14	ST 14	
0045	07 06	RE 6	
0046	02 14	+ 14	Calculate average temperature.
0047	00 02	E 2	
0048	05 14	÷ 14	
0049	08 02	* W	Print \bar{T} .
0050	05 01	÷ 1	
0051	07 01	RE 1	Calculate soil heat flux, G.
0052	06 15	ST 15	
0053	07 02	RE 2	
0054	02 15	+ 15	
0055	07 03	RE 3	
0056	02 15	+ 15	
0057	00 12	E 12	
0058	00 03	E 3	
0059	05 15	÷ 15	
0060	07 14	RE 14	
0061	02 15	+ 15	
0062	00 05	E 5	
0063	04 15	× 15	$G = 5[\bar{T} - (\bar{T}_{-3} + \bar{T}_{-2} + \bar{T}_{-1})/3]$
0064	09 01	* ST	
0065	01 00	T 0	
0066	07 02	RE 2	
0067	06 01	ST 1	$\bar{T}_{-3} = \bar{T}_{-2}$
0068	07 03	RE 3	
0069	06 02	ST 2	$\bar{T}_{-2} = \bar{T}_{-1}$
0070	07 14	RE 14	
0071	06 03	ST 3	$\bar{T}_{-1} = \bar{T}$
0072	07 07	RE 7	
0073	10 00	f 0	Call vapor pressure subroutine, dewpoint.
0074	06 07	ST 7	e_d
0075	07 05	RE 5	
0076	06 14	ST 14	Calculate clear day net radiation, R_{bo} .
0077	00 10	E 10	
0078	00 00	E 0	
0079	00 00	E 0	
0080	00 08	E 8	
0081	00 06	E 6	
0082	00 04	E 4	

Step	Code	Key	Comments
0083	04 14	$\times 14$	
0084	00 03	E 3	
0085	00 10	E 10	
0086	00 09	E 9	
0087	00 07	E 7	
0088	02 14	+ 14	
0089	08 12	* x^2	
0090	08 12	* x^2	
0091	06 14	ST 14	
0092	07 06	RE 6	
0093	06 15	ST 15	
0094	00 10	E 10	
0095	00 00	E 0	
0096	00 00	E 0	
0097	00 08	E 8	
0098	00 06	E 6	
0099	00 04	E 4	
0100	04 15	$\times 15$	
0101	00 03	E 3	
0102	00 10	E 10	
0103	00 09	E 9	
0104	00 07	E 7	
0105	02 15	+ 15	
0106	08 12	* x^2	
0107	08 12	* x^2	
0108	02 14	+ 14	
0109	07 07	RE 7	
0110	08 13	* \sqrt{x}	
0111	06 15	ST 15	
0112	00 10	E 10	
0113	00 00	E 0	
0114	00 04	E 4	
0115	00 04	E 4	
0116	00 12	E 12	
0117	04 15	$\times 15$	
0118	00 10	E 10	
0119	00 03	E 3	
0120	00 07	E 7	
0121	02 15	+ 15	
0122	07 14	RE 14	
0123	04 15	$\times 15$	
0124	07 04	RE 4	
0125	06 14	ST 14	

Calculate clear sky solar radiation, R_{so} .

Step	Code	Key	Comments
0126	00 01	E 1	
0127	00 00	E 0	
0128	00 07	E 7	
0129	03 14	-14	
0130	00 01	E 1	
0131	00 05	E 5	
0132	00 07	E 7	
0133	05 14	÷14	
0134	08 12	* x^2	
0135	08 11	* e^x	
0136	06 14	ST14	
0137	00 07	E 7	
0138	00 06	E 6	
0139	00 00	E 0	
0140	05 14	÷14	
0141	07 08	RE 8	Calculate net radiation, R_n .
0142	04 14	×14	
0143	00 10	E 10	
0144	00 09	E 9	
0145	04 14	×14	
0146	00 10	E 10	
0147	00 01	E 1	
0148	02 14	+14	
0149	04 15	×15	
0150	00 10	E 10	
0151	00 07	E 7	
0152	00 07	E 7	
0153	04 08	×8	
0154	07 15	RE 15	
0155	03 08	-8	
0156	07 05	RE 5	Vapor pressure at maximum temperature.
0157	10 00	f 0	e_s
0158	06 05	ST 5	
0159	07 06	RE 6	
0160	10 00	f 0	e_s
0161	02 05	+5	
0162	00 02	E 2	
0163	05 05	÷5	Average vapor pressure.
0164	08 02	* W	Print e_s .
0165	03 03	-3	
0166	07 07	RE 7	
0167	08 02	* W	Print dewpoint vapor pressure.
0168	14 03	C 3	

Step	Code	Key	Comments
0169	03 05	-5	
0170	07 03	RE 3	Calculate weighting factor $C_2 = f(\bar{T})$.
0171	06 14	ST14	
0172	00 04	E 4	
0173	00 05	E 5	
0174	00 03	E 3	
0175	00 04	E 4	
0176	09 02	* α	
0177	11 08	F 8	
0178	04 14	$\times 14$	
0179	00 10	E10	
0180	00 00	E 0	
0181	00 01	E 1	
0182	00 02	E 2	
0183	00 05	E 5	
0184	03 14	-14	
0185	07 03	RE 3	
0186	04 14	$\times 14$	
0187	00 10	E10	
0188	00 09	E 9	
0189	00 05	E 5	
0190	00 09	E 9	
0191	02 14	+14	
0192	00 01	E 1	
0193	06 06	ST 6	Calculate weighting factor $C_1 = 1 - C_2$.
0194	07 14	RE14	
0195	03 06	-6	
0196	07 09	RE 9	
0197	06 15	ST15	Calculate potential E_{tp} .
0198	00 10	E10	
0199	00 00	E 0	
0200	00 01	E 1	
0201	00 07	E 7	
0202	04 15	$\times 15$	
0203	00 01	E 1	
0204	00 10	E10	
0205	00 01	E 1	
0206	02 15	+15	
0207	04 14	$\times 14$	
0208	00 01	E 1	
0209	00 05	E 5	
0210	00 10	E10	
0211	00 03	E 3	

Step	Code	Key	Comments
0212	00 06	E 6	
0213	04 14	$\times 14$	
0214	07 05	RE 5	
0215	04 14	$\times 14$	
0216	08 01	* RE	
0217	01 00	T 0	
0218	08 02	* W	Print G.
0219	05 02	$\div 2$	
0220	00 12	E 12	
0221	06 15	ST 15	
0222	07 08	RE 8	
0223	08 02	* W	Print R_n .
0224	07 00	RE 0	
0225	02 15	+ 15	
0226	07 06	RE 6	
0227	04 15	$\times 15$	
0228	02 14	+ 14	
0229	00 06	E 6	
0230	00 07	E 7	
0231	00 03	E 3	
0232	09 02	* α	
0233	11 06	F 6	
0234	04 14	$\times 14$	
0235	08 02	* W	Print E_{tp} .
0236	06 03	SI 3	
0237	07 04	RE 4	
0238	02 14	+ 14	
0239	15 11	D 11	
0240	06 00	ST 0	Store date + E_{tp} .
0241	00 01	E 1	
0242	02 00	+ 0	Increment register number.
0243	00 01	E 1	
0244	02 04	+ 4	Increment date.
0245	08 02	* W	
0246	00 15	E 15	
0247	08 02	* W	Print 2 spaces.
0248	00 15	E 15	
0249	07 00	RE 0	
0250	06 14	ST 14	
0251	00 05	E 5	
0252	00 06	E 6	
0253	03 14	- 14	
0254	08 04	* Jo	

Step	Code	Key	Comments
0255	08 00	* S	If register number ≤ 55 , GO TO Step 12.
0256	00 01	E 1	
0257	09 03	* SP	
0258	09 00	* M	Vapor pressure subroutine.
0259	10 00	f 0	
0260	06 15	SI15	
0261	06 14	SI14	
0262	00 08	E 8	
0263	00 09	E 9	
0264	09 02	* α	
0265	11 06	F 6	
0266	04 15	$\times 15$	
0267	00 10	E10	
0268	00 00	E 0	
0269	00 00	E 0	
0270	00 05	E 5	
0271	00 01	E 1	
0272	00 09	E 9	
0273	00 05	E 5	
0274	03 15	-15	
0275	07 14	Rt14	
0276	04 15	$\times 15$	
0277	00 10	E10	
0278	00 02	E 2	
0279	00 09	E 9	
0280	00 04	E 4	
0281	00 06	E 6	
0282	02 15	+15	
0283	04 14	$\times 14$	
0284	00 10	E10	
0285	00 06	E 6	
0286	00 09	E 9	
0287	00 05	E 5	
0288	00 09	E 9	
0289	03 14	-14	
0290	09 15	* RT	
0291	09 14	* EP	

2. Wang Model 700, Verify Number 5671

Step	Code	Key	Comments
000	04 12	Write alpha	
001	12 00	Printer on	To start, key PRIME, G0.
002	01 08	CR/LF	
003	04 13	End alpha	Print heading for ET calculations.
004	04 11	Write	
005	15 10	10 spaces	
006	04 12	Write alpha	
007	01 03	Shift up	
008	02 09	L	
009	01 09	O	
010	02 12	C	
011	01 12	A	
012	02 07	T	
013	01 04	I	
014	01 09	O	
015	02 06	N	
016	04 13	End alpha	
017	04 11	Write	
018	15 15	15 spaces	
019	04 12	Write alpha	
020	01 03	Shift up	
021	02 00	B	
022	02 05	E	
023	00 15	G	
024	01 04	I	
025	02 06	N	
026	02 06	N	
027	01 04	I	
028	02 06	N	
029	00 15	G	
030	00 02	space	
031	02 13	D	
032	01 12	A	
033	02 07	T	
034	02 05	E	
035	00 02	space	
036	12 01	Printer off	
037	04 13	End alpha	
038	05 15	Stop	With printer in manual operation, type the beginning date or
039	04 12	Write alpha	first day of update. Return printer to automatic control.
040	12 00	Printer on	Key G0.
041	01 08	CR/LF	
042	01 10	Index (LF)	
043	01 03	Shift up	
044	00 02	space	
045	02 13	D	
046	01 12	A	
047	00 01	Y	
048	00 02	space	
049	00 02		
050	00 02		

Step	Code	Key	Comments
051	00 02		
052	00 02		
053	00 02		
054	02 07	T	
055	01 12	A	
056	01 14	V	Average temperature.
057	00 15	G	
058	00 02	space	
059	00 02		
060	00 02		
061	00 02		
062	00 02		
063	00 02		
064	01 13	R	Solar radiation in Langleys.
065	01 01	S	
066	00 02	space	
067	00 02		
068	00 02		
069	00 02		
070	00 02		
071	00 02		
072	02 14	U	Total wind in miles.
073	01 12	A	
074	00 02	space	
075	00 02		
076	00 02		
077	00 02		
078	00 02		
079	00 02		
080	00 02		
081	00 02		
082	01 14	V	
083	00 05	P	Mean vapor pressure.
084	01 01	S	
085	00 02	space	
086	00 02		
087	00 02		
088	00 02		
089	00 02		
090	00 02		
091	00 02		
092	01 14	V	
093	00 05	P	Vapor pressure at dewpoint.
094	02 13	D	
095	00 02	space	
096	00 02		
097	00 02		
098	00 02		
099	00 02		
100	00 02		
101	01 13	R	
102	02 06	N	Total net radiation.
103	00 02	space	

Step	Code	Key	Comments
104	00 02		
105	00 02		
106	00 02		
107	00 02		
108	00 02		
109	00 02		
110	00 15	G	Soil heat flux.
111	00 02	space	
112	00 02		
113	00 02		
114	00 02		
115	00 02		
116	00 02		
117	00 02		
118	00 02		
119	00 02		
120	02 05	E	
121	01 09	O	Calculated potential ET.
122	01 08	CR/LF	
123	01 10	Index (LF)	
124	01 02	Shift down	
125	04 13	End alpha	
126	05 15	Stop	Key average temperature for 3rd previous day, key G0.
127	04 04	Store Dir	
128	00 01	1	
129	05 15	Stop	Key average temperature for 2nd previous day, key G0.
130	04 04	Store Dir	
131	00 02	2	
132	05 15	Stop	Key average temperature for 1st previous day, key G0.
133	04 04	Store Dir	
134	00 03	3	
135	07 01	1	
136	07 02	2	
137	04 04	Store Dir	Store 1st ET register number in 0.
138	00 00	O	
139	05 15	Stop	Key 1st day of update, key G0.
140	04 04	Store Dir	
141	00 04	4	
142	04 08	Mark	
143	07 01	1	
144	04 15	Recall Y	
145	00 00	O	
146	04 05	Recall Dir	
147	00 04	4	
148	05 04	Store Ind	Store date in ET register.
149	04 11	Write	
150	03 00	3 sp. O sp.	Print date.
151	05 15	Stop	
152	04 04	Store Dir	Key maximum temperature, key G0.
153	00 05	5	
154	05 15	Stop	Key minimum temperature, key G0.
155	04 04	Store Dir	
156	00 06	6	

Step	Code	Key	Comments
157	05 15	Stop	Key dewpoint temperature, key G0.
158	04 04	Store Dir	
159	00 07	7	
160	05 15	Stop	
161	04 04	Store Dir	Key solar radiation, key G0.
162	00 08	8	
163	05 15	Stop	Key wind in miles, key G0.
164	04 04	Store Dir	
165	00 09	9	
166	04 15	Recall Y	
167	00 05	5	
168	04 05	Recall Dir	
169	00 06	6	
170	06 00	+	
171	07 02	2	
172	06 03	÷	Calculate average temperature.
173	06 05	↓	
174	04 11	Write	Print average temp.
175	07 01	7.1	
176	04 05	Recall Dir	
177	00 02	2	Calculate soil heat flux.
178	04 00	+ Dir	
179	00 01	1	
180	04 05	Recall Dir	$G = 5 \left[\bar{T} - (\bar{T}_{-3} + \bar{T}_{-2} + \bar{T}_{-1})/3 \right]$
181	00 03	3	
182	04 00	+ Dir	
183	00 01	1	
184	07 03	3	
185	04 03	÷ Dir	
186	00 01	1	
187	04 05	Recall Dir	
188	00 01	1	
189	04 14	Store Y	
190	00 01	1	
191	06 01	—	
192	07 05	5	
193	06 02	×	
194	04 14	Store Y	Store G in 21.
195	02 01	21	
196	04 05	Recall Dir	
197	00 01	1	
198	04 06	↑↓ Dir	$\bar{T}_{-3} = \bar{T}_{-2}$
199	00 03	3	
200	04 06	↑↓ Dir	$\bar{T}_{-2} = \bar{T}_{-1}$
201	00 02	2	
202	04 06	↑↓ Dir	$\bar{T}_{-1} = \bar{T}$
203	00 01	1	
204	04 05	Recall Dir	
205	00 07	7	
206	02 00	Call Sub.	Calculate Vapor pressure at dewpoint temperature.
207	04 14	Store Y	Subroutine starts at step 584.
208	00 07	7	
209	04 15	Recall Y	

Step	Code	Key	Comments
210	00 05	5	Calculate clear day net radiation, R_{bo} .
211	07 12	•	
212	07 00	0	
213	07 00	0	
214	07 08	8	
215	07 06	6	
216	07 04	4	
217	06 02	×	
218	07 03	3	
219	07 12	•	
220	07 09	9	
221	07 07	7	
222	06 00	+	
223	06 05	↓	
224	07 13	X^2	
225	07 13	X^2	
226	04 04	Store Dir	
227	02 00	20	
228	04 15	Recall Y	
229	00 06	6	
230	07 12	•	
231	07 00	0	
232	07 00	0	
233	07 08	8	
234	07 06	6	
235	07 04	4	
236	06 02	×	
237	07 03	3	
238	07 12	•	
239	07 09	9	
240	07 07	7	
241	06 00	+	
242	06 05	↓	
243	07 13	X^2	
244	07 13	X^2	
245	04 00	+ Dir	
246	02 00	20	
247	04 05	Recall Dir	
248	00 07	7	
249	06 12	\sqrt{X}	
250	06 04	↑	
251	07 12	•	
252	07 00	0	
253	07 04	4	
254	07 04	4	
255	07 11	Ch. sign	
256	06 02	×	
257	07 12	•	
258	07 03	3	
259	07 07	7	
260	06 00	+	
261	06 05	↓	
262	04 02	× Dir	

Step	Code	Key	Comments
263	02 00	20	
264	04 15	Recall Y	Calculate clear sky solar radiation, R_{so} .
265	00 04	4	
266	07 01	1	
267	07 00	0	
268	07 07	7	
269	06 01	—	
270	07 01	1	
271	07 05	5	
272	07 07	7	
273	06 03	÷	
274	06 05	↓	
275	07 13	X ²	
276	06 14	e ^x	
277	06 04	↑	
278	07 07	7	
279	07 06	6	
280	07 00	0	
281	06 03	÷	
282	04 05	Recall Dir	Calculate net radiation, R_n .
283	00 08	8	
284	04 11	Write	Print solar radiation.
285	08 00	8.0	
286	06 02	×	
287	07 12	•	
288	07 09	9	
289	06 02	×	
290	07 12	•	
291	07 01	1	
292	06 00	+	
293	04 05	Recall Dir	
294	02 00	20	
295	06 02	×	
296	07 12	•	
297	07 07	7	
298	07 07	7	
299	04 02	×	Dir
300	00 08	8	
301	06 05	↓	
302	04 01	—	Dir
303	00 08	8	
304	04 05	Recall Dir	
305	00 05	5	Vapor pressure at maximum temperature.
306	02 00	Call Sub.	
307	04 14	Store Y	
308	00 05	5	
309	04 05	Recall Dir	
310	00 06	6	Vapor pressure at minimum temperature.
311	02 00	Call Sub.	
312	06 05	↓	
313	04 00	+	Dir
314	00 05	5	
315	07 02	2	

Step	Code	Key	Comments
316	04 03	\div Dir	
317	00 05	5	Average vapor pressure.
318	04 05	Recall Dir	
319	00 09	9	
320	04 11	Write	Print wind.
321	06 01	6.1	
322	04 05	Recall Dir	
323	00 05	5	
324	04 11	Write	
325	07 01	7.1	Print average vapor pressure.
326	04 05	Recall Dir	
327	00 07	7	
328	04 11	Write	
329	06 01	6.1	Print dewpoint vapor pressure.
330	04 01	— Dir	
331	00 05	5	
332	04 15	Recall Y	Calculate weighting factor C_2 .
333	00 03	3	
334	07 04	4	
335	07 05	5	
336	07 03	3	
337	07 04	4	
338	04 12	Write alpha	
339	04 08	$\times 10^{-8}$	
340	06 02	\times	
341	07 12	•	
342	07 00	0	
343	07 01	1	
344	07 02	2	
345	07 05	5	
346	06 01	—	
347	04 05	Recall Dir	
348	00 03	3	
349	06 02	—	
350	07 12	•	
351	07 09	9	
352	07 05	5	
353	07 09	9	
354	06 00	+	
355	07 01	1	
356	04 04	Store Dir	Calculate weighting factor $C_1 = 1 - C_2$.
357	00 06	6	
358	06 05	\downarrow	
359	04 01	— Dir	
360	00 06	6	Calculate potential E_{tp} .
361	07 12	•	
362	07 00	0	
363	07 01	1	
364	07 07	7	
365	04 02	\times Dir	
366	00 09	9	
367	07 01	1	
368	07 12	•	

Step	Code	Key	Comments
369	07 01	1	
370	04 00	+ Dir	
371	00 09	9	
372	04 05	Recall Dir	
373	00 09	9	
374	06 02	×	
375	07 01	1	
376	07 05	5	
377	07 12	•	
378	07 03	3	
379	07 06	6	
380	06 02	×	
381	04 05	Recall Dir	
382	00 05	5	
383	06 02	×	
384	04 05	Recall Dir	
385	00 08	8	
386	04 11	Write	
387	08 00	8.0	Print net radiation, R_n .
388	04 05	Recall Dir	
389	02 01	21	
390	04 11	Write	Print G.
391	06 01	6.1	
392	04 01	— Dir	
393	00 08	8	
394	04 05	Recall Dir	
395	00 06	6	
396	04 02	×	Dir
397	00 08	8	
398	04 05	Recall Dir	
399	00 08	8	
400	06 00	+	
401	07 06	6	
402	07 07	7	
403	07 03	3	
404	04 12	Write alpha	
405	04 06	×	10^{-6}
406	06 02	×	
407	06 05	↓	
408	04 11	Write	Print potential E_{tp} in inches.
409	05 03	5.3	
410	04 05	Recall Dir	
411	00 04	4	
412	06 00	+	Date + E_{tp} .
413	06 05	↓	
414	04 15	Recall Y	
415	00 00	0	
416	05 04	Store Ind	Store date + E_{tp} .
417	07 01	1	
418	04 00	+ Dir	
419	00 00	0	Increment register number.
420	04 00	+ Dir	
421	00 04	4	Increment date.

Step	Code	Key	Comments
422	04 12	Write alpha	
423	01 08	CR/LF	
424	04 13	End alpha	
425	04 15	Recall Y	
426	00 00	0	
427	07 01	1	
428	07 06	6	
429	05 09	Skip if Y = X	
430	04 07	Search	If register number < 16, GO TO Step 142.
431	07 01	1	
432	05 15	Stop	
433	04 08	Mark	When ET calculations are completed, insert new page in
434	07 02	2	printer and key Search 2. Headings for the scheduling
435	04 11	Write	program are printed.
436	15 10	10 spaces	
437	04 12	Write alpha	
438	01 03	Shift up	
439	02 09	L	
440	01 09	O	
441	02 12	C	
442	01 12	A	
443	02 07	T	
444	01 04	I	
445	01 09	O	
446	02 06	N	
447	00 02	space	
448	00 02		
449	04 13	End alpha	
450	04 11	Write	
451	15 15	15 spaces	
452	04 12	Write alpha	
453	01 03	Shift up	
454	02 00	B	
455	02 05	E	
456	00 15	G	
457	01 04	I	
458	02 06	N	
459	02 06	N	
460	01 04	I	
461	02 06	N	
462	00 15	G	
463	00 02	space	
464	02 13	D	
465	01 12	A	
466	02 07	T	
467	02 05	E	
468	00 02	space	
469	12 01	Printer off	
470	04 13	End alpha	
471	05 15	Stop	Turn printer to manual, type date, return printer to auto,
472	04 12	Write alpha	key G0.
473	12 00	Printer on	
474	01 08	CR/LF	

Step	Code	Key	Comments
475	01 10	Index (LF)	
476	01 03	Shift up	
477	00 14	F	
478	01 04	I	
479	02 05	E	
480	02 09	L	
481	02 13	D	
482	00 02	space	
483	00 02		
484	00 02		
485	00 02		
486	02 13	D	
487	02 05	E	
488	00 05	P	
489	02 09	L	
490	02 05	E	
491	02 07	T	
492	01 04	I	
493	01 09	O	
494	02 06	N	
495	00 02	space	
496	00 02		
497	00 02		
498	00 02		
499	00 02		
500	00 02		
501	00 02		
502	00 02		
503	02 13	D	
504	01 12	A	
505	00 01	Y	
506	00 02	space	
507	02 07	T	
508	01 09	O	
509	00 02	space	
510	01 04	I	
511	01 13	R	
512	01 13	R	
513	01 04	I	
514	00 15	G	
515	01 12	A	
516	02 07	T	
517	02 05	E	
518	00 02	space	
519	00 02		
520	00 02		
521	00 02		
522	00 02		
523	01 12	A	
524	01 15	M	
525	01 09	O	
526	02 14	U	
527	02 06	N	

Step	Code	Key	Comments
528	02 07	T	
529	00 02	space	
530	02 07	T	
531	01 09	O	
532	00 02	space	
533	01 12	A	
534	00 05	P	
535	00 05	P	
536	02 09	L	
537	00 01	Y	
538	01 08	CR/LF	
539	04 13	End alpha	
540	04 11	Write	
541	15 09	9 spaces	
542	04 12	Write alpha	
543	02 05	E	
544	01 01	S	
545	02 07	T	
546	01 06	•	
547	00 02	space	
548	00 02		
549	00 02		
550	00 02		
551	00 02		
552	01 09	O	
553	00 05	P	
554	02 07	T	
555	01 06	•	
556	04 13	End alpha	
557	04 11	Write	
558	15 12	12 spaces	
559	04 11	Write	
560	15 12	12 spaces	
561	04 12	Write alpha	
562	01 04	I	
563	02 06	N	
564	02 12	C	
565	02 01	H	
566	02 05	E	
567	01 01	S	
568	00 02	space	
569	00 02		
570	00 02		
571	01 12	A	
572	02 12	C	
573	01 13	R	
574	02 05	E	
575	01 02	Shift down	
576	00 00	—	
577	01 03	Shift up	
578	01 04	I	
579	02 06	N	
580	01 06	•	

Step	Code	Key	Comments
581	01 08	CR/LF	
582	04 13	End alpha	
583	05 15	Stop	
584	04 08	Mark	Subroutine for calculating vapor pressure as a function of temperature.
585	02 00	Sub.	
586	06 04	↑	
587	04 04	Store Dir	
588	00 10	10	
589	07 08	8	
590	07 09	9	
591	04 12	Write alpha	
592	04 06	$\times 10^{-6}$	
593	06 02	\times	
594	07 12	•	
595	07 00	0	
596	07 00	0	
597	07 05	5	
598	07 01	1	
599	07 09	9	
600	07 05	5	
601	06 01	—	
602	04 05	Recall Dir	
603	00 10	10	
604	06 02	\times	
605	07 12	•	
606	07 02	2	
607	07 09	9	
608	07 04	4	
609	07 06	6	
610	06 00	+	
611	06 05	↓	
612	04 02	\times Dir	
613	00 10	10	
614	07 12	•	
615	07 06	6	
616	07 09	9	
617	07 05	5	
618	07 09	9	
619	04 01	— Dir	
620	00 10	10	
621	04 15	Recall Y	
622	00 10	10	
623	05 11	Return	
624	05 12	End program	

B. Irrigation Scheduling Programs

1. Wang Model 600, Verify Number 5863 (version 11/28/72)

Step	Code	Key	Comments
0000	00 05	E 5	To start, key PRIME, GO.
0001	00 01	E 1	
0002	09 02	* α	Read field data from tape, store in registers
0003	08 01	* RE	16-51, two registers per field.
0004	00 01	E 1	
0005	00 06	E 6	
0006	06 12	ST 12	Set first field register number in register 12.
0007	09 00	* M	
0008	00 01	E 1	
0009	00 10	E 10	Initialize registers 1-3.
0010	00 00	E 0	
0011	00 01	E 1	
0012	06 03	ST 3	
0013	06 02	ST 2	
0014	06 01	ST 1	
0015	15 11	D 11	
0016	07 12	RE 12	Recall data for one field, unpack data and
0017	09 02	* α	store in keyboard registers.
0018	11 10	F 10	
0019	06 14	ST 14	
0020	09 12	* I	
0021	06 11	ST 11	Store field number in 11.
0022	03 14	- 14	
0023	09 02	* α	
0024	10 07	f 7	
0025	06 14	ST 14	
0026	09 12	* I	
0027	06 05	ST 5	Store efficiency, acres, optimum depletion
0028	03 14	- 14	per foot in 5.
0029	09 02	* α	
0030	10 01	f 1	
0031	06 06	ST 6	Store depletion in 6.
0032	00 01	E 1	
0033	02 12	+ 12	Increment register number.
0034	15 11	D 11	
0035	07 12	RE 12	Recall second half of field data, unpack.
0036	09 02	* α	
0037	11 10	F 10	
0038	06 14	ST 14	
0039	09 12	* I	

Step	Code	Key	Comments
0040	06 15	ST15	
0041	04 01	$\times 1$	Store rainfall or irrigation for previous 3 days.
0042	07 15	RE15	R_{-1} in 1.
0043	03 14	-14	
0044	09 02	* α	
0045	10 02	f 2	
0046	06 14	ST14	
0047	09 12	* I	
0048	06 15	ST15	
0049	04 02	$\times 2$	Store R_{-2} in 2.
0050	07 15	RE15	
0051	03 14	-14	
0052	09 02	* α	
0053	10 02	f 2	
0054	06 14	ST14	
0055	09 12	* I	
0056	06 15	ST15	
0057	04 03	$\times 3$	Store R_{-3} in 3.
0058	07 15	RE15	
0059	03 14	-14	
0060	09 02	* α	
0061	10 03	f 3	
0062	06 14	ST14	
0063	09 12	* I	
0064	06 04	ST 4	Store planting date in 4.
0065	03 14	-14	
0066	09 02	* α	
0067	10 03	f 3	
0068	09 12	* I	
0069	06 00	ST 0	Store effective cover date in 0.
0070	00 05	E 5	
0071	00 02	E 2	
0072	06 13	ST13	Set first Penman register number in register 13.
0073	09 00	* M	
0074	00 04	E 4	
0075	15 11	D11	
0076	07 13	RE13	Recall date + Penman potential, E_{tp} .
0077	06 14	ST14	
0078	09 12	* I	
0079	06 08	ST 8	Store date in 8.
0080	03 14	-14	
0081	09 04	* J_+	
0082	08 00	* S	If $E_{tp} = 0$, GO TO Step 383.

Step	Code	Key	Comments
0083	02 15	+15	
0084	06 10	ST10	Store E_{tp} in 10.
0085	07 11	RE11	
0086	09 02	* α	
0087	11 05	F 5	
0088	06 14	ST14	
0089	07 08	RE 8	Display date and field number, Stop.
0090	02 14	+14	If Field number is zero, REWIND tape, key LOAD
0091	09 03	* SP	PROG, SEARCH 0. Updated data is stored on tape.
0092	06 09	ST 9	If field number is non zero, key rainfall +
0093	09 00	* M	irrigation amount for the date displayed,
0094	04 14	$\times 14$	key G0.
0095	07 05	RE 5	Store $R + I$ in 9.
0096	09 02	* α	Recall and unpack optimum depletion in inches
0097	11 02	F 2	per foot, store in 7.
0098	06 14	ST14	
0099	09 12	* I	
0100	03 14	-14	
0101	06 07	ST 7	
0102	07 08	RE 8	
0103	06 14	ST14	
0104	09 02	* α	
0105	08 05	* J ₊	
0106	08 00	* S	If Date is after effective cover, GO TO Step 341.
0107	00 05	E 5	
0108	07 04	RE 4	
0109	00 12	E12	
0110	06 15	ST15	
0111	02 14	+14	
0112	07 00	RE 0	$r = \frac{(\text{Date} - \text{Planting date})}{(\text{Eff. Cover} - \text{Planting})}$
0113	02 15	+15	
0114	05 14	$\div 14$	
0115	06 15	ST15	Store r in 15.
0116	00 03	E 3	Calculate root zone depth.
0117	00 10	E10	
0118	00 05	E 5	For corn, $D_r = .5 + 3.5 r$.
0119	04 15	$\times 15$	
0120	00 00	E 0	
0121	00 10	E10	
0122	00 05	E 5	
0123	02 15	+15	
0124	04 07	$\times 7$	Optimum depletion in inches, D_o in 7.
0125	07 14	RE14	

Step	Code	Key	Comments
0126	06 15	ST15	Calculate crop coefficient, K_c , before
0127	00 01	E 1	effective cover.
0128	00 10	E10	$K_{co} = Ar^3 + Br^2 + Cr + D$
0129	00 05	E 5 -----	Constant A.
0130	00 08	E 8	
0131	00 03	E 3	
0132	00 12	E12	
0133	04 14	$\times 14$	
0134	00 02	E 2 -----	Constant B.
0135	00 10	E10	
0136	00 07	E 7	
0137	00 05	E 5	
0138	00 06	E 6	
0139	02 14	$+14$	
0140	07 15	RE15	
0141	04 14	$\times 14$	
0142	00 10	E10 -----	Constant C.
0143	00 04	E 4	
0144	00 02	E 2	
0145	00 07	E 7	
0146	00 06	E 6	
0147	00 12	E12	
0148	02 14	$+14$	
0149	04 15	$\times 15$	
0150	00 00	E 0 -----	Constant D.
0151	00 10	E10	
0152	00 02	E 2	
0153	00 01	E 1	
0154	00 03	E 3	
0155	02 15	$+15$	K_{co} stored in 15.
0156	09 00	* M	
0157	00 06	E 6	
0158	07 15	RE15	
0159	06 14	ST14	
0160	00 01	E 1	
0161	03 14	-14	
0162	00 12	E12	
0163	08 05	* J	If $K_{co} > 1$, $K_{co} = 1$.
0164	00 01	E 1	
0165	06 15	ST15	
0166	07 06	RE 6	Reduce crop coefficient for stress.
0167	06 14	ST14	
0168	00 05	E 5	Ratio of optimum depletion to total depletion in percent.

Step	Code	Key	Comments
0169	00 00	E 0	
0170	04 14	× 14	
0171	07 07	RE 7	
0172	05 14	÷ 14	$K_c = K_{co} \frac{1n(101 - 50 \times D_p / D_o)}{1n(101)}$
0173	00 09	E 9	
0174	00 09	E 9	
0175	03 14	- 14	
0176	08 05	* J _s	
0177	08 00	* S	If $D_p < .99 \times$ Total depletion, GO TO Step 184.
0178	03 14	- 14	
0179	00 10	E 10	$D_p = D_p - .1$
0180	00 01	E 1	
0181	03 06	- 6	
0182	08 00	* S	GO TO Step 156.
0183	00 06	E 6	
0184	09 00	* M	
0185	03 14	- 14	
0186	00 12	E 12	
0187	06 14	ST 14	
0188	00 02	E 2	
0189	02 14	+ 14	
0190	08 10	* LN	
0191	04 15	× 15	
0192	00 01	E 1	
0193	00 00	E 0	
0194	00 01	E 1	
0195	08 10	* LN	
0196	05 15	÷ 15	Adjusted K_c in 15.
0197	00 10	E 10	
0198	00 09	E 9	
0199	06 14	ST 14	
0200	07 15	RE 15	
0201	03 14	- 14	
0202	08 05	* J _s	If $K_c \geq .9$, GO TO Step 240.
0203	08 00	* S	
0204	00 08	E 8	
0205	07 10	RE 10	Calculate additional E_t from rain or irrigation within three prior days.
0206	04 14	× 14	
0207	07 01	RE 1	
0208	09 04	* J _s	
0209	08 00	* S	If $R_{-1} = 0$, GO TO Step 317.
0210	00 09	E 9	
0211	00 10	E 10	

Step	Code	Key	Comments
0212	00 08	E 8	$E_{tr} = .8 \times (.9 - K_c) \times E_{tp}$
0213	04 14	$\times 14$	
0214	03 01	- 1	$R_{-1} = R_{-1} - E_{tr}$
0215	00 12	E12	
0216	08 05	* J+	
0217	08 00	* S	If $R_{-1} \geq 0$, GO TO Step 236.
0218	00 11	E11	
0219	03 02	- 2	$R_{-2} = R_{-2} - R_{-1}, R_{-1} = 0$
0220	01 01	T 1	
0221	07 02	RE 2	
0222	09 00	* M	
0223	00 12	E12	
0224	00 12	E12	
0225	08 05	* J+	
0226	08 00	* S	If $R_{-2} \geq 0$, GO TO Step 236.
0227	00 11	E11	
0228	03 03	- 3	$R_{-3} = R_{-3} - R_{-2}, R_{-2} = 0$
0229	01 02	T 2	
0230	09 00	* M	
0231	00 03	E 3	
0232	07 03	RE 3	
0233	08 05	* J+	
0234	02 14	+14	If $R_{-3} < 0, E_{tr} = E_{tr} + R_{-3}.$
0235	08 03	* G _o	
0236	09 00	* M	
0237	00 11	E11	
0238	07 14	RE14	
0239	02 06	+ 6	$D_p = D_p + E_{tr}$
0240	09 00	* M	
0241	00 08	E 8	Calculate depletion.
0242	07 15	RE15	
0243	04 10	$\times 10$	
0244	02 06	+ 6	
0245	07 01	RE 1	
0246	14 02	C 2	
0247	06 03	SI 3	
0248	07 09	RE 9	$R_{-2} = R_{-1}, R_{-3} = R_{-2}$
0249	06 01	SI 1	$R_{-1} = R + I$
0250	03 06	- 6	$D_p = D_p + K_c \times E_{tp} - (R + I)$
0251	08 05	* J+	
0252	00 00	E 0	If $D_p < 0, D_p = 0.$
0253	06 06	SI 6	
0254	00 10	E10	

Step	Code	Key	Comments
0255	00 09	E 9	
0256	03 09	- 9	
0257	00 12	E12	
0258	08 05	* J ₊	
0259	07 09	RE 9	If $(R + I) \geq .9$, $R_{-1} = .9$.
0260	03 01	- 1	
0261	00 01	E 1	
0262	02 13	+13	Increment Penman register number.
0263	06 14	SI14	
0264	00 05	E 5	
0265	00 06	E 6	
0266	03 14	-14	
0267	08 05	* J ₊	
0268	08 00	* S	If reg. number ≤ 55 , GO TO Step 73.
0269	00 04	E 4	
0270	09 04	* J ₊	
0271	08 00	* S	If reg. number = 56, GO TO Step 383.
0272	02 15	+15	
0273	09 00	* M	
0274	04 15	$\times 15$	
0275	07 07	RE 7	
0276	06 14	SI14	
0277	07 06	RE 6	
0278	03 14	-14	
0279	08 05	* J ₊	
0280	08 00	* S	If $D_p > D_o$, GO TO Step 450.
0281	00 15	E15	
0282	00 02	E 2	
0283	00 04	E 4	
0284	00 05	E 5	
0285	06 14	SI14	
0286	07 08	RE 8	
0287	03 14	-14	
0288	08 05	* J ₊	
0289	08 00	* S	If date \geq Nov. 1, GO TO Step 456.
0290	02 14	+14	
0291	00 10	E10	
0292	00 03	E 3	Set maximum average potential E_{ta} .
0293	06 10	SI10	Calculate average potential E_{ta}
0294	00 01	E 1	
0295	00 03	E 3	If date ≤ 137 , /date = 150.
0296	00 07	E 7	
0297	06 14	SI14	If date > 137 , /date = 95.

Step	Code	Key	Comments
0298	00 05	E 5	$-\left[\frac{\text{Date} - 137}{\text{Idate}}\right]^2$
0299	00 05	E 5	
0300	06 15	SI 15	$E_{ta} = 0.3 \times e$
0301	00 01	E 1	Increment Date.
0302	02 08	+ 8	
0303	03 14	- 14	
0304	08 05	* J	
0305	00 00	E 0	
0306	06 15	SI 15	
0307	00 09	E 9	
0308	00 05	E 5	
0309	02 15	+ 15	
0310	05 14	÷ 14	
0311	08 12	* x^2	Store E_{ta} in 10. $(R + I) = 0$.
0312	08 11	* e^x	
0313	05 10	÷ 10	GO TO Step 93.
0314	01 09	T 9	
0315	08 00	* S	
0316	04 14	× 14	
0317	09 00	* M	
0318	00 09	E 9	
0319	07 02	÷ 2	
0320	09 04	* J	
0321	08 00	* S	If $R_{-2} = 0$, GO TO Step 329.
0322	00 10	E 10	
0323	00 10	E 10	
0324	00 05	E 5	
0325	04 14	× 14	$E_{tr} = 0.5 \times (.9 - K_c) \times E_{tp}$
0326	03 02	- 2	$R_{-2} = R_{-2} - E_{tr}$ GO TO Step 222.
0327	08 00	* S	
0328	00 12	E 12	
0329	09 00	* M	
0330	00 10	E 10	
0331	07 03	KE 3	
0332	09 04	* J	
0333	08 00	* S	
0334	00 08	E 8	If $R_{-3} = 0$, GO TO Step 240.
0335	00 10	E 10	
0336	00 03	E 3	$E_{tr} = 0.3 \times (.9 - K_c) \times E_{tp}$
0337	04 14	× 14	
0338	03 03	- 3	$R_{-3} = R_{-3} - E_{tr}$ GO TO Step 230.
0339	08 00	* S	
0340	00 03	E 3	

Step	Code	Key	Comments
0341	09 00	* M	Calculate crop coefficient after effective cover.
0342	00 05	E 5	
0343	07 00	RE 0	
0344	03 14	-14	$r = (\text{Date} - \text{effective cover date})$
0345	06 15	ST 15	
0346	00 02	E 2	----- Constant A.
0347	00 07	E 7	
0348	00 05	E 5	
0349	00 11	E 11	
0350	00 12	E 12	
0351	00 08	E 8	
0352	04 14	$\times 14$	
0353	00 04	E 4	----- Constant B.
0354	00 06	E 6	
0355	00 08	E 8	
0356	00 08	E 8	
0357	00 12	E 12	
0358	00 11	E 11	
0359	00 12	E 12	
0360	00 07	E 7	
0361	02 14	+14	
0362	07 15	RE 15	
0363	04 14	$\times 14$	
0364	00 10	E 10	----- Constant C.
0365	00 00	E 0	
0366	00 01	E 1	
0367	00 01	E 1	
0368	00 09	E 9	
0369	00 05	E 5	
0370	02 14	+14	
0371	04 15	$\times 15$	
0372	00 10	E 10	----- Constant D.
0373	00 09	E 9	
0374	00 01	E 1	
0375	00 05	E 5	
0376	02 15	+15	K_c stored in 15.
0377	00 04	E 4	Set rooting depth.
0378	00 10	E 10	
0379	00 00	E 0	
0380	04 07	$\times 7$	Calculate optimum depletion in inches.
0381	08 00	* S	GO TO Step 156.
0382	00 06	E 6	
0383	09 00	* M	

Step	Code	Key	Comments
0384	02 15	+15	
0385	08 02	* W	
0386	00 15	E15	
0387	08 02	* W	Print two spaces.
0388	00 15	E15	
0389	07 11	RE11	
0390	08 02	* W	Print field number.
0391	08 00	* S	
0392	07 06	RE 6	
0393	08 02	* W	Print depletion.
0394	06 02	ST 2	
0395	00 01	E 1	Decrement data register number.
0396	03 12	-12	
0397	07 07	RE 7	
0398	08 02	* W	Print optimum depletion.
0399	03 02	- 2	
0400	07 05	RE 5	Repack field data.
0401	09 02	* α	
0402	11 07	F 7	
0403	02 11	+11	
0404	09 02	* α	
0405	10 08	f 8	
0406	06 11	ST11	
0407	07 06	RE 6	
0408	02 11	+11	
0409	09 02	* α	
0410	10 02	f 2	
0411	15 11	D11	Store field number, efficiency, acres, optimum
0412	06 12	ST12	depletion per foot, depletion.
0413	00 01	E 1	
0414	02 12	+12	Increment register number.
0415	00 01	E 1	Repack second half of field data.
0416	00 00	E 0	
0417	00 00	E 0	
0418	06 14	ST14	
0419	07 01	RE 1	
0420	04 14	$\times 14$	
0421	09 12	* I	
0422	06 14	ST14	
0423	07 02	RE 2	
0424	02 14	+14	
0425	09 02	* α	
0426	10 02	f 2	

Step	Code	Key	Comments
0427	09 12	* I	
0428	06 14	SI14	
0429	07 03	RE 3	
0430	02 14	+14	
0431	09 02	* α	
0432	10 02	f 2	
0433	09 12	* I	
0434	09 02	* α	
0435	10 03	f 3	
0436	06 14	SI14	
0437	07 04	RE 4	
0438	02 14	+14	
0439	09 02	* α	
0440	10 03	f 3	
0441	06 14	SI14	
0442	07 00	RE 0	
0443	02 14	+14	
0444	15 11	D11	Store R_{-1} , R_{-2} , R_{-3} , planting date, effective cover date.
0445	06 12	SI12	
0446	00 01	E 1	
0447	02 13	+13	Increment Penman register number.
0448	08 00	* S	GO TO Step 273.
0449	04 15	$\times 15$	
0450	09 00	* M	
0451	00 15	E15	
0452	07 10	RE10	Calculate irrigation day.
0453	05 14	$\div 14$	
0454	09 12	* I	
0455	02 08	+8	
0456	09 00	* M	
0457	02 14	+14	$\text{Date} = \text{Date} + \text{INT} \left\{ \frac{D_o - D_p}{K_c \times E_{tp}} \right\}$
0458	08 02	* W	
0459	11 00	F 0	Print day to irrigate.
0460	08 02	* W	
0461	00 15	E15	Space printer.
0462	07 05	RE 5	
0463	09 02	* α	
0464	11 02	F 2	
0465	09 12	* I	
0466	09 02	* α	
0467	11 05	F 5	
0468	06 14	SI14	Inches to apply = D_p / Efficiency.
0469	05 06	$\div 6$	

Step	Code	Key	Comments
0470	08 02	* W	Print depth to apply.
0471	02 01	+ 1	
0472	00 01	E 1	Unpack acres.
0473	00 00	E 0	
0474	00 00	E 0	
0475	04 14	× 14	
0476	09 12	* I	
0477	03 14	- 14	
0478	09 02	* α	
0479	10 02	f 2	
0480	04 06	× 6	
0481	08 02	* W	Print acre-inches to apply.
0482	01 01	T 1	
0483	00 01	E 1	
0484	02 12	+ 12	Increment register number.
0485	06 14	ST 14	
0486	00 05	E 5	
0487	00 02	E 2	
0488	03 14	- 14	
0489	08 04	* J ₀	
0490	08 00	* S	If field number < 52, GO TO Step 7.
0491	00 01	E 1	
0492	09 03	* SP	Rewind tape, key PRIME, LOAD PROG,
0493	09 00	* M	SEARCH 0.
0494	00 00	E 0	
0495	00 05	E 5	Write updated data on tape.
0496	00 01	E 1	
0497	09 02	* α	
0498	09 01	* ST	
0499	09 03	* SP	Stop
0500	09 14	* EP	End

2. Wang Model 700A, Verify Number 7503

Step	Code	Key	Comments
000	04 12	Write alpha	
001	01 10	Index (LF)	To start, key PRIME, G0.
002	01 03	Shift up	
003	02 12	C	Print crop name.
004	01 09	O	
005	01 13	R	
006	02 06	N	
007	00 02	space	
008	00 02		
009	00 02		
010	01 02	shift down	
011	01 08	CR/LF	
012	04 13	End alpha	
013	07 02	2	Store in register 120 the starting register number (20) for
014	07 00	0	field data.
015	04 04	Store Dir	
016	12 00	120	
017	04 08	Mark	
018	07 01	1	
019	04 15	Recall Y	Recall data for one field.
020	12 00	120	
021	05 05	Recall Ind	Unpack data.
022	04 12	Write alpha	
023	04 03	÷ Dir	
024	06 04	↑	
025	06 08	Integer X	
026	06 01	—	
027	04 12	Write alpha	
028	04 07	$\times 10^{-7}$	
029	04 04	Store Dir	Field, efficiency, acres, optimum depletion per foot in
030	00 05	5	register 5.
031	06 06	↑↓	
032	04 12	Write alpha	
033	07 01	$\times 10$	
034	04 04	Store Dir	Depletion, inches in register 6.
035	00 06	6	
036	07 01	1	
037	04 00	+ Dir	Increment field register number.
038	12 00	120	
039	04 15	Recall Y	Recall second half of data.
040	12 00	120	
041	05 05	Recall Indir	
042	04 12	Write alpha	
043	04 00	$\times 10^{-10}$	
044	06 04	↑	
045	06 08	Integer X	
046	04 04	Store Dir	Rainfall and/or irrigation for previous day, R_{-1} in
047	00 01	1	register 1.
048	06 01	—	
049	06 05	↓	
050	04 12	Write alpha	

Step	Code	Key	Comments
051	07 02	$\times 100$	
052	06 04	\uparrow	
053	06 08	Integer X	
054	04 04	Store Dir	
055	00 02	2	R_{-2} in register 2.
056	06 01	—	
057	06 05	\downarrow	
058	04 12	Write alpha	
059	07 02	$\times 100$	
060	06 04	\uparrow	
061	06 08	Integer X	
062	04 04	Store Dir	R_{-3} in register 3.
063	00 03	3	
064	06 01	—	
065	07 12	•	
066	07 00	0	Change decimal to correct position for previous rainfall.
067	07 01	1	
068	04 02	$\times \text{Dir}$	
069	00 01	1	
070	04 02	$\times \text{Dir}$	
071	00 02	2	
072	04 02	$\times \text{Dir}$	
073	00 03	3	
074	06 05	\downarrow	
075	04 12	Write alpha	
076	07 03	$\times 1000$	
077	06 04	\uparrow	
078	06 08	Integer X	
079	04 04	Store Dir	Planting date in register 4.
080	00 04	4	
081	06 01	—	
082	06 05	\downarrow	
083	04 12	Write alpha	
084	07 03	$\times 1000$	
085	06 08	Integer X	
086	04 04	Store Dir	Effective cover date in register 0.
087	00 00	0	
088	07 01	1	
089	07 02	2	
090	04 04	Store Dir	First Penman-Date register number (12) in register 121.
091	12 01	121	
092	04 08	Mark	
093	07 04	4	
094	04 15	Recall Y	
095	12 01	121	
096	05 05	Recall Indir	Recall Date + E_{tp} .
097	06 04	\uparrow	
098	06 08	Integer X	
099	04 04	Store Dir	Store date in register 8.
100	00 08	8	
101	06 01	—	
102	07 00	0	

Step	Code	Key	Comments
103	06 06	↑↓	
104	05 08	Skip if Y < X	
105	04 07	Search	
106	06 00	+	If $E_{tp} = 0$, GO TO Step 474.
107	04 04	Store Dir	
108	00 10	10	Store E_{tp} in 10.
109	04 15	Recall Y	
110	00 08	8	
111	04 05	Recall Dir	
112	00 05	5	Display date in register Y, field number in X, stop.
113	06 08	Integer X	
114	05 15	Stop	Key Rain + Irrigation for date shown, GO.
115	04 04	Store Dir	
116	00 09	9	
117	04 08	Mark	
118	06 01	—	
119	04 05	Recall Dir	
120	00 05	5	Recall and unpack optimum depletion per foot.
121	04 12	Write alpha	
122	07 05	$\times 10^5$	
123	06 04	↑	
124	06 08	Integer X	
125	06 01	—	
126	04 14	Store Y	Store optimum depletion per foot in 7.
127	00 07	7	
128	04 15	Recall Y	
129	00 08	8	
130	04 05	Recall Dir	
131	00 00	0	
132	05 08	Skip if Y < X	
133	04 07	Search	If Date \geq Effective cover date, GO TO Step 341.
134	07 05	5	
135	04 05	Recall Dir	
136	00 04	4	Calculate fraction of time from planting to effective cover.
137	06 01	—	
138	07 11	Ch. sign	
139	04 06	↑↓ Dir	
140	00 00	0	
141	04 00	+ Dir	$r = \frac{(\text{Date} - \text{planting date})}{(\text{Effective cover} - \text{planting})}$
142	00 00	0	
143	04 06	↑↓ Dir	
144	00 00	0	
145	06 03	÷	
146	06 05	↓	
147	04 04	Store Dir	Store r in 11.
148	00 11	11	
149	07 03	3	Calculate rooting depth.
150	07 12	•	
151	07 05	5	
152	06 02	\times	
153	07 00	0	
154	07 12	•	

Step	Code	Key	Comments
155	07 05	5	
156	06 00	+	
157	06 05	↓	
158	04 02	× Dir	Calculate optimum depletion in 7.
159	00 07	7	
160	04 15	Recall Y	
161	00 11	11	Calculate crop coefficient.
162	07 01	1 -----	Constant A.
163	07 12	•	
164	07 05	5	
165	07 08	8	
166	07 03	3	
167	07 11	ch. sign	
168	06 02	×	
169	07 02	2 -----	Constant B.
170	07 12	•	
171	07 07	7	
172	07 05	5	
173	07 06	6	
174	06 00	+	
175	04 05	Recall Dir	
176	00 11	11	
177	06 02	×	
178	07 12	• -----	Constant C.
179	07 04	4	
180	07 02	2	
181	07 07	7	
182	07 06	6	
183	07 11	ch. sign	
184	06 00	+	
185	06 05	↓	
186	04 02	× Dir	
187	00 11	11	
188	07 12	• -----	Constant D.
189	07 02	2	
190	07 01	1	
191	07 03	3	
192	04 00	+ Dir	
193	00 11	11	Crop coefficient K_c in 11.
194	04 08	Mark	
195	07 06	6	
196	04 15	Recall Y	
197	00 11	11	
198	07 01	1	
199	05 08	Skip if $Y < X$	
200	04 04	Store Dir	If $K_c > 1$, $K_c = 1$.
201	00 11	11	
202	04 15	Recall Y	Reduce crop coefficient for stress.
203	00 06	6	
204	07 05	5 -----	Ratio of optimum depletion to total depletion in percent.
205	07 00	0	
206	06 02	×	

Step	Code	Key	Comments
207	04 05	Recall Dir	
208	00 07	7	
209	06 03	\div	
210	07 09	9	
211	07 09	9	
212	05 07	Skip if $Y \geq X$	
213	04 07	Search	If depletion < 99 percent total depletion, GO TO Step 221.
214	07 07	7	
215	07 12	•	
216	07 01	1	
217	04 01	— Dir	$D_p = D_p - 0.1$
218	00 06	6	
219	04 07	Search	GO TO Step 194.
220	07 06	6	
221	04 08	Mark	
222	07 07	7	
223	07 01	1	
224	07 00	0	
225	07 01	1	
226	06 01	—	
227	06 11	ln X	
228	04 03	\div Dir	
229	00 11	11	
230	06 05	\downarrow	
231	07 11	ch. sign	
232	06 11	ln X	
233	04 02	\times Dir	Adjusted K_c in 11.
234	00 11	11	
235	04 05	Recall Dir	
236	00 10	10	
237	06 04	\uparrow	
238	04 06	$\uparrow\downarrow$ Dir	
239	00 11	11	E_{tp} in 11.
240	06 02	\times	
241	04 14	Store Y	
242	00 10	10	$E_t = K_c \times E_{tp}$ in 10.
243	06 04	\uparrow	
244	07 12	•	
245	07 09	9	
246	05 08	Skip if $Y < X$	
247	04 07	Search	If $K_c \geq 0.9$, GO TO Step 308.
248	07 08	8	
249	06 06	$\uparrow\downarrow$	
250	06 01	—	
251	06 05	\downarrow	
252	04 02	\times Dir	
253	00 11	11	$(.9 - K_c) \times E_{tp}$ in 11.
254	04 15	Recall Y	
255	00 01	1	
256	07 00	0	
257	06 06	$\uparrow\downarrow$	
258	05 08	Skip if $Y < X$	

Step	Code	Key	Comments
259	04 07	Search	If $R_{-1} = 0$, GO TO Step 800.
260	07 09	9	Calculate additional E_t from rain or irrigation within three
261	07 12	•	previous days.
262	07 08	8	
263	04 02	× Dir	$E_{tr} = .8 \times (.9 - K_c) \times E_{tp}$
264	00 11	11	
265	04 05	Recall Dir	
266	00 11	11	
267	04 01	− Dir	$R_{-1} = R_{-1} - E_{tr}$
268	00 01	1	
269	04 15	Recall Y	
270	00 01	1	
271	07 00	0	
272	05 08	Skip if $Y < X$	
273	04 07	Search	If $R_{-1} \geq 0$, GO TO Step 302.
274	07 10	set exp	
275	04 04	Store Dir	$R_{-1} = 0$
276	00 01	1	
277	06 05	↓	
278	04 00	+ Dir	$R_{-2} = R_{-2} + R_{-1}$
279	00 02	2	
280	04 08	Mark	
281	07 11	ch. sign	
282	04 15	Recall Y	
283	00 02	2	
284	07 00	0	
285	05 08	Skip if $Y < X$	
286	04 07	Search	If $R_{-2} \geq 0$, GO TO Step 302.
287	07 10	set exp	
288	04 04	Store Dir	$R_{-2} = 0$
289	00 02	2	
290	06 05	↓	
291	04 00	+ Dir	$R_{-3} = R_{-3} + R_{-2}$
292	00 03	3	
293	04 08	Mark	
294	07 03	3	
295	04 15	Recall Y	
296	00 03	3	
297	07 00	0	
298	06 06	↑↓	
299	05 08	Skip if $Y < X$	
300	04 00	+ Dir	If $R_{-3} \leq 0$, $E_{tr} = E_{tr} + R_{-3}$.
301	00 11	11	
302	04 08	Mark	
303	07 10	set exp	
304	04 05	Recall Dir	
305	00 11	11	Adjust depletion.
306	04 00	+ Dir	$D_p = D_p + E_{tr}$
307	00 06	6	
308	04 08	Mark	
309	07 08	8	
310	04 05	Recall Dir	

Step	Code	Key	Comments
311	00 10	10	
312	04 00	+ Dir	$D_p = D_p + E_t$
313	00 06	6	
314	04 05	Recall Dir	
315	00 09	9	
316	04 01	- Dir	$D_p = D_p - (\text{Rain} + \text{Irrigation})$
317	00 06	6	
318	04 15	Recall Y	
319	00 06	6	
320	07 00	0	
321	05 07	Skip if $Y \geq X$	
322	04 04	Store Dir	If $D_p < 0$, $D_p = 0$.
323	00 06	6	
324	04 05	Recall Dir	
325	00 01	1	
326	04 06	\rightarrow Dir	$R_{-2} = R_{-1}$
327	00 02	2	
328	04 06	\rightarrow Dir	$R_{-3} = R_{-2}$
329	00 03	3	
330	04 15	Recall Y	
331	00 09	9	
332	07 12	•	
333	07 09	9	
334	05 08	Skip if $Y < X$	
335	06 06	$\uparrow\downarrow$	If $(R + I) \geq .9$, $(R + I) = .9$.
336	05 14	Go	
337	04 14	Store Y	$R_{-1} = (R + I)$
338	00 01	1	
339	04 07	Search	GO TO Step 388.
340	06 14	e^x	
341	04 08	Mark	Calculate crop coefficient after effective cover.
342	07 05	5	
343	06 01	-	
344	04 14	Store Y	$r = \text{Date} - \text{Effective cover date}$.
345	00 11	11	
346	07 02	2 -----	Constant A.
347	07 07	7	
348	07 05	5	
349	07 10	set exp	
350	07 11	ch. sign	
351	07 05	5	
352	06 02	\times	
353	07 04	4 -----	Constant B.
354	07 06	6	
355	07 08	8	
356	07 08	8	
357	07 11	ch. sign	
358	07 10	set exp	
359	07 11	ch. sign	
360	07 03	3	
361	06 00	+	
362	04 05	Recall Dir	

Step	Code	Key	Comments
363	00 11	11	
364	06 02	×	
365	07 12	•	----- Constant C.
366	07 00	0	
367	07 01	1	
368	07 01	1	
369	07 09	9	
370	07 05	5	
371	06 00	+	
372	06 05	↓	
373	04 02	× Dir	
374	00 11	11	
375	07 12	•	----- Constant D.
376	07 09	9	
377	07 01	1	
378	07 05	5	
379	04 00	+ Dir	
380	00 11	11	
381	07 04	4	Root zone depth in feet.
382	07 12	•	
383	07 00	0	
384	04 02	× Dir	
385	00 07	7	Optimum depletion in 7.
386	04 07	Search	GO TO Step 194.
387	07 06	6	
388	04 08	Mark	
389	06 14	e ^x	
390	07 01	1	
391	04 00	+ Dir	Increment Penman, date register.
392	12 01	121	
393	04 15	121	
394	12 01	Recall Y	
395	07 01	1	
396	07 06	6	
397	05 07	Skip if $Y \geq X$	
398	04 07	Search	If Penman reg. < 16, GO TO Step 92.
399	07 04	4	
400	05 09	Skip if $Y = X$	
401	04 07	Search	If Penman reg. > 16, GO TO Step 405.
402	06 03	÷	
403	04 07	Search	If Penman reg. = 16, GO TO Step 474.
404	06 00	+	
405	04 08	Mark	
406	06 03	÷	
407	04 05	Recall Dir	
408	00 07	7	
409	04 15	Recall Y	Compare depletion to optimum depletion, D_o .
410	00 06	6	
411	05 08	Skip if $Y < X$	
412	04 07	Search	If $D_p \geq D_o$, GO TO Step 546.
413	06 02	×	
414	07 01	1	

Step	Code	Key	Comments
415	04 00	+ Dir	Increment date.
416	00 08	8	
417	04 15	Recall Y	
418	00 08	8	
419	07 02	2	
420	07 04	4	
421	07 07	7	
422	05 08	Skip if Y < X	
423	04 07	Search	If date ≥ 247 , GO TO Step 558.
424	07 02	2	
425	07 01	1	Calculate average potential, E_{ta} .
426	07 03	3	
427	07 07	7	
428	06 01	—	
429	07 00	0	
430	05 08	Skip if Y < X	
431	04 07	Search	If date ≥ 137 , GO TO Step 819.
432	07 13	X^2	
433	07 01	1	$I_{date} = 150$.
434	07 05	5	
435	07 00	0	
436	04 08	Mark	
437	06 12	\sqrt{X}	
438	06 03	\div	
439	06 05	\downarrow	
440	07 13	X^2	
441	06 14	e^x	
442	06 15	$1/X$	
443	06 04	\uparrow	
444	07 12	•	
445	07 03	3	
446	07 00	0	
447	06 02	\times	
448	04 14	Store Y	Store E_{ta} in 10.
449	00 10	10	
450	07 00	0	
451	04 04	Store Dir	$(R + I) = 0$
452	00 09	9	
453	04 07	Search	GO TO Step 117.
454	06 01	—	
455	04 08	Mark	
456	07 12	•	
457	04 15	Recall Y	
458	00 03	3	
459	07 00	0	
460	06 06	$\uparrow\downarrow$	
461	05 08	Skip if Y < X	
462	04 07	Search	If $R_{-3} \leq 0$, GO TO Step 308.
463	07 08	8	
464	07 12	•	
465	07 03	3	
466	04 02	\times Dir	$E_{tr} = .3 \times (.9 - K_c) \times E_{tp}$

Step	Code	Key	Comments
467	00 11	11	
468	04 05	Recall Dir	
469	00 11	11	
470	04 01	- Dir	$R_{-3} = R_{-3} - E_{tr}$
471	00 03	3	
472	04 07	Search	GO TO Step 293.
473	07 03	3	
474	04 08	Mark	
475	06 00	+	
476	04 05	Recall Dir	
477	00 05	5	
478	06 08	Integer X	
479	04 11	Write	Print field number.
480	03 00	3.0	
481	04 05	Recall Dir	
482	00 06	6	
483	04 11	Write	Print depletion.
484	05 02	5.2	
485	04 12	Write alpha	
486	07 02	$\times 100$	
487	06 04	\uparrow	
488	04 05	Recall Dir	
489	00 07	7	
490	04 11	Write	Print optimum depletion.
491	05 02	5.2	
492	07 01	1	
493	04 01	- Dir	Decrement field register.
494	12 00	120	
495	04 05	Recall Dir	Repack field data.
496	00 05	5	
497	04 12	Write alpha	
498	07 00	$\times 10^{10}$	
499	06 00	+	
500	06 05	\downarrow	
501	04 15	Recall Y	
502	12 00	120	
503	05 04	Store Indir	Store field data.
504	07 01	1	
505	04 00	+ Dir	Increment field register.
506	12 00	120	
507	04 00	+ Dir	Increment Penman register.
508	12 01	121	
509	04 15	Recall Y	
510	00 00	0	
511	04 05	Recall Dir	Repack second half of data.
512	00 04	4	
513	04 12	Write alpha	
514	07 03	$\times 1000$	
515	06 00	+	
516	04 05	Recall Dir	
517	00 03	3	
518	04 12	Write alpha	

Step	Code	Key	Comments
519	07 02	$\times 100$	
520	06 08	Integer X	
521	04 12	Write alpha	
522	07 06	$\times 10^6$	
523	06 00	+	
524	04 05	Recall Dir	
525	00 02	2	
526	04 12	Write Alpha	
527	07 02	$\times 100$	
528	06 08	Integer X	
529	04 12	Write alpha	
530	07 08	$\times 10^8$	
531	06 00	+	
532	04 05	Recall Dir	
533	00 01	1	
534	04 12	Write alpha	
535	07 02	$\times 100$	
536	06 08	Integer X	
537	04 12	Write alpha	
538	07 00	$\times 10^{10}$	
539	06 00	+	
540	06 05	↓	
541	04 15	Recall Y	
542	12 00	120	
543	05 04	Store Indir	Store second half of data.
544	04 07	Search	GO TO Step 405.
545	06 03	÷	
546	04 08	Mark	
547	06 02	\times	
548	06 01	—	
549	04 05	Recall Dir	
550	00 10	10	
551	06 03	÷	
552	06 05	↓	
553	06 08	Integer X	
554	04 01	— Dir	Adjust irrigation day if $D_p > D_o$.
555	00 08	8	
556	04 05	Recall Dir	
557	00 08	8	
558	04 08	Mark	
559	07 02	2	
560	04 11	Write	Print irrigation day.
561	08 00	8.0	
562	04 11	Write	
563	15 10	10 spaces	
564	04 05	Recall Dir	Unpack efficiency, calculate inches to apply.
565	00 05	5	
566	06 04	↑	
567	06 08	Integer X	
568	06 01	—	
569	06 05	↓	
570	04 03	÷ Dir	

Step	Code	Key	Comments
571	00 06	6	
572	04 12	Write alpha	
573	07 02	$\times 100$	
574	06 04	\uparrow	
575	06 08	Integer X	
576	06 01	—	
577	06 05	\downarrow	
578	04 12	Write alpha	
579	07 03	$\times 1000$	
580	06 08	Integer X	
581	04 12	Write alpha	
582	04 01	$\times 10^{-1}$	
583	06 04	\uparrow	
584	04 05	Recall Dir	
585	00 06	6	
586	06 02	\times	
587	04 11	Write	Print inches to apply.
588	05 01	5.1	
589	06 05	\downarrow	
590	04 11	Write	Print acre-inches to apply.
591	08 01	8.1	
592	04 12	write alpha	
593	01 08	CR/LF	
594	04 13	End alpha	
595	07 01	1	
596	04 00	+ Dir	Increment register number.
597	12 00	120	
598	04 15	Recall Y	
599	12 00	120	
600	07 04	4	
601	07 04	4	
602	05 07	Skip if Y > X	
603	04 07	Search	If reg. number < 44, GO TO Step 17.
604	07 01	1	
605	05 15	Stop	
606	05 15	Stop	
607	05 15	Stop	

Steps 608-799 contain field data.

800	04 08	Mark	
801	07 09	9	
802	04 15	Recall Y	
803	00 02	2	
804	07 00	0	
805	06 06	$\uparrow\downarrow$	
806	05 08	Skip if Y < X	
807	04 07	Search	If $R_{-2} \leq 0$, GO TO Step 455.
808	07 12	•	
809	07 12	•	
810	07 05	5	

Step	Code	Key	Comments
811	04 02	× Dir	$E_{tr} = .5 \times (.9 - K_c) \times E_{tp}$
812	00 11	11	
813	04 05	Recall Dir	
814	00 11	11	
815	04 01	— Dir	$R_{-2} = R_{-2} - E_{tr}$
816	00 02	2	
817	04 07	Search	GO TO Step 280.
818	07 11	ch. sign	
819	04 08	Mark	
820	07 13	X ²	
821	07 00	0	ldate = 95
822	07 09	9	
823	07 05	5	
824	04 07	Search	GO TO Step 436.
825	06 12	\sqrt{X}	
826	05 12	End Program	

C. Changes Required for Different Locations

1. Adapting the Scheduling Programs for Other Crops

600	Step	700	Change
		3- 9	Name.
116-118		149-151 {	Rooting depth constants (table 3).
120-122		153-155 }	
127-132		162-167	Constant A } Before effective cover equation 3 (table 2).
134-138		169-173	
142-147		178-183	
150-154		188-191	
168-169		204-205	Ratio of optimum depletion to total depletion.
346-351		346-351	Constant A } After effective cover equation 3 (table 2).
353-360		353-360	
364-469		365-370	
372-375		375-378	
377-379		381-382	Decimal occurs prior to first digit when entering in this manner on 700.
			Root zone after effective cover (table 3).
291-292		425-427 {	Coefficients for equation 2.
294-296		433-435 }	
298-299 ¹		444-446 }	
307-308		821-823 }	

¹ Coefficient is a difference between Δ DAY before and after effective cover.

2. Modifying the Penman Programs for a New Calibration

600	Step	700	Coefficient
112-116		251-255	-.044 (equation 1i)
118-120		257-259	.37 (equation 1i)
126-128		266-268	107 (equation 1h)
130-132		270-272	157 (equation 1h)
137-139		278-280	760 (equation 1h)
143-144		287-288	.9 (equation 1g)
146-147		290-291	.1 (equation 1g)

D. Changes for Model 700A to 700B

Step	700A	700B
016	120	42
020	120	42
038	120	42
040	120	42
091	121	43
095	121	43
392	121	43
394	121	43
494	120	42
502	120	42
506	120	42
508	121	43
542	120	42
597	120	42
599	120	42
601	4	2

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